RL/REG-2000-18
Revision 0

REGULATORY UNIT ASSESSMENT ON THE USE OF THE TWRS FSAR TO ESTIMATE RISK

July 14, 2000

Office of Safety Regulation of the RPP-WTP Contractor

U.S. Department of Energy
Richland Operations Office
P.O. Box 550, A4-70
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Approved: ______________________________
Regulatory Official

Date: __________________________________

PREFACE

T The Department of Energy's (DOE) Richland Operations Office (RL) issued the *TWRS Privatization Request for Proposal* (RFP) for Hanford Tank Waste Remediation System (TWRS) Privatization in February 1996. Offerors were requested to submit proposals for the initial processing of the tank waste at Hanford. Some of this radioactive waste has been stored in large underground storage tanks at the Hanford Site since 1944. Currently, approximately 54 million gallons of waste containing approximately 240,000 metric tons of processed chemicals and 250 mega-curies of radionuclides are being stored in 177 tanks. These caustic wastes are in the form of liquids, slurries, saltcakes, and sludges. The wastes stored in the tanks are defined as high-level radioactive waste (10 CFR Part 50, Appendix F) and hazardous waste (Resource Conservation and Recovery Act).

The contract concept was for DOE to enter into a fixed-price contract for the contractor to build and operate a facility to treat the waste according to DOE specifications. The TWRS Privatization Program was divided into two phases, Phase I and Phase II. Phase I was a proof-of-concept/commercial demonstration-scale effort the objectives of which were to (a) demonstrate the technical and business viability of using privatized contractors to treat Hanford tank waste; (b) define and maintain adequate levels of radiological, nuclear, and process safety; (c) maintain environmental protection and compliance; and (d) substantially reduce life-cycle costs and time required to treat the tank waste. The Phase I effort consisted of two parts: Part A and Part B.

Part A consisted of a twenty-month development period to establish appropriate and necessary technical, operational, regulatory, business, and financial elements. This included identification by the TWRS Privatization Contractors and approval by DOE of appropriate safety standards, formulation by the Contractors and approval by DOE of integrated safety management plans, and preparation by the Contractors and evaluation by DOE of initial safety assessments. Of the twenty-month period, sixteen months were used by the Contractors to develop the Part-A products and four months were used by DOE to evaluate the products.

Part B was to consist of a demonstration period to provide tank waste treatment services by the TWRS Privatization Contractors who successfully completed Part A. Demonstration was to address a range of wastes representative of those in the Hanford tanks. Part B was to be 10 to 14 years in duration. Within Part B, wastes were to be processed during a 5- to 9-year period resulting in treatment of 6 to 13 percent of the Hanford tank waste.

Phase II was to be a full-scale production phase in which the remaining tank waste would be processed on a schedule that would accomplish removal from all single-shelled tanks by the year 2018. The objectives of Phase II were to a) implement the lessons learned from Phase I; and b) process all tank waste into forms suitable for final disposal.

In May 2000, DOE chose to terminate the privatization contract and seek new bidders under a different contract strategy. The program name was also changed from the Tank Waste Remediation System to the River Protection Project (RPP). The RPP is under the direction of the Office of River Protection, which was created by Congress in 1998 to assume programmatic responsibility for the entire Tank Waste Remediation System, including the waste treatment plant (WTP).

A key element of the River Protection Project Waste Treatment Plant (RPP-WTP) is DOE regulation of safety through a specifically chartered, dedicated Regulatory Unit (RU) at RL. This regulation by the RU is authorized by the document entitled *Policy for Safety Regulation of the RPP-WTP Contractor* (referred to as the Policy) and implemented through the document entitled *Memorandum of Agreement for the Execution of Safety Regulation of the RPP-WTP Contractor* (referred to as the MOA). The Under Secretary of Energy; the Assistant Secretary for Environment, Safety and Health (ASEH); and the Assistant Secretary for Environmental Management (ASEM) signed the Policy. The MOA is signed by the ASEH and the ASEM. The nature and characteristics of this regulation are also specified in these documents. The MOA details certain interactions among RL, the ASEH, and the ASEM as well as their respective roles and responsibilities for implementation of this regulation.

The authority of the RU to regulate the RPP-WTP Contractor is derived solely from the terms of the RPP-WTP Contract. Its authority to regulate the Contractor on behalf of DOE is derived from the Policy. The nature and scope of this special regulation (in the sense that it is based on terms of a contract rather than formal regulations) is delineated in the MOA, the RPP-WTP Contract, and the documents, listed below, which are incorporated into the Contract. This special regulation by the RU in no way replaces any legally established external regulatory authority to regulate in accordance with duly promulgated regulations nor relieves the Contractor from any obligations to comply with such regulations or to be subject to the enforcement practices contained therein.

The Policy, the MOA, the RPP-WTP Contract, and the documents incorporated in the Contract define the essential elements of the regulatory program, which are being executed by the RU and to which the RPP-WTP Contractor must conform. The four radiological, nuclear and process safety-related documents incorporated in the Contract (and also incorporated in the MOA) are:

> *Concept of the DOE Process for Radiological, Nuclear, and Process Safety Regulation of the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0005,
>
> *DOE Process for Radiological, Nuclear, and Process Safety Regulation of the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0003,
>
> *Top-Level Radiological, Nuclear, and Process Safety Standards and Principles for the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0006, and
>
> *Process for Establishing a Set of Radiological, Nuclear, and Process Safety Standards and Requirements for the RPP Waste Treatment Plant Contractor,* DOE/RL-96-0004.

The two non-radiological safety documents are:

> *Industrial Hygiene and Safety Regulatory Plan*, RL/REG-2000-04, and
>
> *Regulatory Unit Position on Regulation of the Contractor's Industrial Hygiene and Safety Program* , RL/REG-99-11.

In the execution of the regulatory program, the RU considers not only the relevant approaches and practices of DOE but also those of the U.S. Nuclear Regulatory Commission (NRC) and the Occupational Safety and Health Administration (OSHA). The Policy states that

> "It is DOE's policy that the RPP-WTP Contractor activities be regulated in a manner that assures adequate safety by application of regulatory concepts and principles consistent with those of the Nuclear Regulatory Commission and the Occupational Safety and Health Administration."

To this end, the RU interacts with the NRC and the OSHA during development and execution of its regulatory program.

All documents issued by the Office of Safety Regulation of the RPP-WTP Contractor are available to the public through the DOE/RL Public Reading Room at the Consolidated Information Center, Room 101L, Richland, Washington. Copies may be purchased for a duplication fee.

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REGULATION UNIT ASSESSMENT ON THE USE OF THE TWRS FSAR TO ESTIMATE RISK

1.0 PURPOSE

This paper presents an assessment on using the risk profile as documented in the Tank Waste Remediation System (TWRS) Final Safety Analysis Report (FSAR) to estimate the risk to the public and onsite co-located worker from TWRS, also known as the tank farms, which is part of the facility managed by the U.S. Department of Energy (DOE), Office of River Protection (ORP).

2.0 BACKGROUND

The purpose for the retrieval and treatment of the radioactive/hazardous waste currently contained in TWRS is to protect the public health and safety and to reduce the potential for adverse environmental impact.

Estimates of the relative risk posed by TWRS and the River Protection Project Waste Treatment Plant (RPP-WTP) are potentially useful to support the regulatory process for RPP-WTP. The DOE Contract DE-AC27-96RL13308,[1] which contains the regulatory requirements, requires that risk estimates be made to assure risk goals for the RPP-WTP facility are met. No equivalent requirement exists for TWRS. However, the FSAR produced in compliance with DOE 5480.23, *Nuclear Safety Analysis Reports*, has been published for TWRS. It contains the results of the TWRS safety analysis produced in accordance with the guidance in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*.

The safety analysis results, which are both quantitative and qualitative, address the frequency and consequences of potential accidents and hazardous conditions at TWRS. The quantitative safety analysis results include dose and frequency computations for a set of potential TWRS accidents. This report reviews and summarizes these results, and considers whether the quantitative safety analysis results produced for the FSAR can be used to estimate any fraction of the risk from TWRS for use in comparative risk studies with the RPP-WTP.

3.0 DISCUSSION

3.1 Perspectives on the use of TWRS FSAR Results to Estimate Risk

The U.S. Nuclear Regulatory Commission (NRC) standard review plan, NUREG 0800, *Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision making: General*

[1] Contract No. DE-AC27-96RL13308, between DOE and BNFL Inc., dated August 24, 1998.

Guidance, Chapter 19.0, describes the use of Probabilistic Risk Assessment (PRA) in Plant-Specific, Risk-Informed Decision making. It states that "The approach to risk characterization should establish a cause-effect relationship to identify portions of the PRA affected by the issue being evaluated… This approach will help…determine the scope and level of detail of analysis required…" The risk estimate of TWRS is used in comparisons with the risk of the RPP-WTP. Therefore, the characteristics and level of uncertainty of the TWRS risk estimate should be comparable to that of the RPP-WTP. The main characteristics of interest in a TWRS risk estimate are:

- The contribution of seismic events to TWRS risk.
- Potential transfer operations that would be expected for waste feed and delivery to the treatment plant.
- Events involving evolution and ignition of flammable gas.
- The effects of aging on TWRS risk.

Additional analysis is necessary to provide an appropriate level of detail for use in comparative risk studies. This level of additional detail would be determined by what comparisons would be made and what parameters would be addressed in these comparisons. Quantitative uncertainty analysis would assess the precision of the results to support any comparisons and sensitivity studies. The following results would be required to yield a credible, useful risk estimate:

1. A more comprehensive set of Beyond Evaluation Basis Accidents.
2. Inclusion of the consideration of both operating and safety systems in a quantitative system failure likelihood analyses.
3. Best estimate system success criteria and accident phenomena analysis.
4. Quantitative uncertainty analysis.

Efforts are currently underway as part of the TWRS Nuclear Safety and Licensing Authorization Basis maintenance activities to address some of the bounding conservatisms in the safety analysis. This is especially true of the accidents related to system leaks during waste transfers (spray leaks, surface pool leaks, and subsurface leaks). These efforts primarily address the bounding assumptions which drive the consequence results. Any risk estimate for TWRS will need to consider these updated results to provide a complete, current picture of TWRS risk.

While this assessment concludes that the TWRS FSAR results cannot be used to estimate the risk from TWRS, the results can be used to support development of a risk estimate. Because the FSAR results are bounding, accidents shown to have relatively insignificant dose/frequency results, can be eliminated from consideration in producing the TWRS risk estimate.

3.2 Basis for Assessment

The primary authorization basis (AB) document for TWRS is the FSAR. This document presents the results of the safety analyses performed to evaluate the adequacy of the safety basis for TWRS and establishes the safety envelope within which operations can continue in a safe manner.

The TWRS AB consists of the FSAR, the FSAR comment and approval record (i.e., Safety Evaluation Report [SER]), the associated Technical Safety Requirements (TSRs), and other related documents. Table 3.2-1 lists the TWRS AB documents.

Table 3.2-1. TWRS Authorization Basis Documents.

Document Number	Title
Major TWRS Authorization Basis Documents	
HNF-SD-WM-SAR-067	*Tank Waste Remediation System Final Safety Analysis Report*
TWRS-RT-SER-003	*Safety Evaluation Report for the Tank Waste Remediation System (TWRS) Final Safety Analysis Report (FSAR) and Technical Safety Requirements*
HNF-SD-WM-TSR-006	*Tank Waste Remediation System Technical Safety Requirements*
HNF-SD-WM-TI-764	*Hazard Analysis Database Report*
Other TWRS Authorization Basis Documents	
LA-UR-92-3196	*A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101*
HNF-3337	*Authorization Basis for the 209-E Building*
WHC-SD-WM-TI-789	*Preliminary Hazards Analysis – 209-E Building - Critical Mass Laboratory*
WHC-SD-WM-SAD-035	*A Safety Assessment of Rotary Mode Core Sampling in Single Shell Tanks: Hanford Site, Richland, Washington*
WHC-SD-WM-SSP-002	*242-S Facility Shutdown/Standby Plan*
WHC-SD-HS-SAR-009	*242-T Evaporator Facility Shutdown/Standby to Condition V Safety Analysis Report*
WHC-SD-WM-SSP-005	*Grout Facilities Standby Plan*
WHC-SD-WM-SAR-027	*Hazards Identification and Evaluation Report for the Operation of the Grout Facilities and Near-Surface Disposal of Grouted Phosphate/Sulphate Low Level Liquid Waste*
FDH-9757421A	*Transmittal of Tier II Review Comments on the Safety Analysis for Project W-030, 702-AZ Ventilation System and Interim Direction for Interim Actions*, letter from A. M. Umek, Fluor Daniel Hanford, Inc., to L. E. Hall, Lockheed Martin Hanford Corporation, 1997.

The TWRS FSAR safety analysis was performed in accordance with DOE 5480.23 and the guidance in DOE-STD-3009-94. The safety analysis methods delineated in DOE-STD-3009-94 were applied to the TWRS analysis because TWRS is classified as a Hazard Category 2 facility.[2] The TWRS safety analysis consists of both qualitative and quantitative results including the frequency and consequences of abnormal events and postulated accidents. These safety analysis results constitute a risk profile for TWRS. Comparing the characteristics of the TWRS risk profile to those typically provided in a PRA yields insight on the use of this information to estimate the risk from TWRS.

A set of NRC reports on PRA Methodology, NUREG 4550, *Analysis of Core Damage*

[2] FSAR, page ES-6.

Frequency: Internal Events Methodology, NUREG/CR 4551, *Evaluation of Severe Accident Risks: Methodology for the Containment, Source Term, Consequence, and Risk Integration Analyses*, and NUREG 4840, *Procedures for the External Event Core Damage Frequency Analyses for NUREG-1150*, collectively describe the details of the characteristics of risk estimates developed by the application of PRA methodologies. These types of risk results are used in the NRC licensing process as risk estimates for nuclear power plants. Their characteristics are used as a basis for comparison to determine if the TWRS risk profile can be used in a similar fashion. The major characteristics of a quantitative risk assessment (i.e., PRA) are listed in Table 3.2-2. The Table compares the characteristics of the TWRS risk profile to a quantitative risk assessment. The Table also includes a comparison of the features of the TWRS analysis basis for a typical TWRS accident, the spray leak accident.

Table 3.2-2. Risk Assessment Characteristics.

Analysis Results		
Quantitative Risk Assessment[3]	TWRS Safety Analysis	Spray Leak Accident Analysis[4]
1. Best estimate quantitative results with quantitative uncertainty	• Bounding consequence analysis[5] • Likelihood assessment to place results in likelihood bins • Only qualitative discussion of uncertainties • Best estimate meteorology used in assessment of BEBA[6]	• Assumption that spray produces ideal respirable aerosol • Bounding likelihood assumption • Qualitative discussion of major uncertainties
2. Best estimate system success criteria and accident phenomenology analysis	• System success criteria based on assumption or current practice in TWRS • Accident phenomenology based on bounding assumptions	• Conservative, bounding success criteria assumed[7] • Leak detection systems assumed not to work • Pit assumed to be half filled with liquid waste • Source term assumed to consist of 33% solids
3. Comprehensive set of postulated accidents	• Set of 29 representative accidents analyzed to define the TWRS safety envelope	• N/A

[3] Characteristics of a Probabilistic Risk Assessment (PRA) as described in NUREG/CR 4550, 4551, and 4840.
[4] Analyzed as part of the TWRS Safety Analysis.
[5] As per DOE-STD-3009-94.
[6] Beyond Evaluation Basis Accidents (equivalent to Beyond Design Basis Accidents).
[7] This set of success assumptions is internally inconsistent

Table 3.2-2. Risk Assessment Characteristics.

Analysis Results		
Quantitative Risk Assessment[3]	TWRS Safety Analysis	Spray Leak Accident Analysis[4]
4. Quantitative likelihood analysis including system reliability analysis	• Likelihood analysis affected by simplifications • System failure likelihood based on "rules of thumb"	• Likelihood of spray leak estimated to equal frequency of all leaks • Likelihood assessment of failure of mitigating systems • Results placed in likelihood bins
5. Internal, external, and natural phenomena events addressed	• Seismic event only external event analyzed quantitatively • Only two magnitudes of seismic event considered	• Assumed to be one of the accidents caused by a BEBA seismic event along with a pool leak and flammable gas accident • Assumption includes continued operation of waste transfer pumps during BEBA seismic event (i.e., offsite power unaffected by seismic event)
6. Assessment of failures includes both normally operating and safety systems	• Only systems/actions identified as safety related controls are assessed	• Only includes those systems identified as controls
7. Analysis supports sensitivity studies	• Bounding assumptions do not support sensitivity studies in some cases	• Ideal aerosol assumed • Pit assumed to be half full
8. Complete set of beyond design basis accidents including system failures and events exceeding design basis conditions	• One BEBA seismic event assumed • Only those accidents with uncontrolled consequences above REGs[8] analyzed as BEBA • Phenomenological dose reduction factors incorporated	• Analyzed as a BEBA

Review of Table 3.2-2 suggests that the TWRS risk profile is not useable as an estimate of TWRS risk. The risk profile was designed to define a safety envelope within which safe TWRS operations could take place. Therefore, it was always developed as a bounding case. Further, to develop the bounding case, many of the factors which may be important in a comparative risk study were assumed away. For example, the frequency of a spray leak was assumed to be equal to the more general frequency of leaks without varying the range of possible leak characteristics or the frequency of waste transfers.

Under other conditions, it may be possible to use evaluation basis event analysis information to

[8] Risk Evaluation Guidelines (see Table 5.2-1).

make a rough estimate of risk. As is revealed in the table above, in the case of TWRS, this approach is unrealistic. There are so many differences between the analysis approaches that were used on TWRS and a risk assessment that unacceptable uncertainty would be injected into the estimate. Since the estimate is to be compared with the RPP-WTP risk assessment, the uncertainties in the analyses would not be comparable. Nonetheless, a risk estimate has been drawn from the FSAR data and is discussed below in Section 4.4. It is not considered to have sufficient merit to be used in comparison with the RPP-WTP risk assessment.

The conditions expected to be the significant risk contributors for TWRS are the Beyond Evaluation Basis Accidents (BEBA).[9] Such events include potential cases where safety features are postulated to have failed or conditions exceed the evaluation basis (e.g., a beyond evaluation basis seismic event is postulated to occur). The FSAR includes analysis of a limited number of BEBA. The FSAR BEBA did base the dose calculations on best estimate (e.g., 50%) meteorology, but did not include a best estimate source term, system success criteria or realistic accident phenomena. Because the effects of these factors on the risk calculations are not necessarily linear and in some instances, may have competing effects, the BEBA results can not be simply factored to derive a reasonable risk estimate.

Table 4.4-2 shows the highest consequence events[10] are the seismic event, leak accidents (e.g., pool and spray leaks), tank bump accident, and the organic salt-nitrate accident using the analysis assumptions described above. A recent change to the FSAR states that conditions for the organic salt-nitrate accident do not exist in the tanks. Currently efforts are underway, as part of the Phase 2 FSAR implementation, to reevaluate the spray leak and tank bump accidents to determine if the calculated consequences are unnecessarily conservative.

The following sections of this paper summarize the details of the TWRS FSAR safety analysis approach and results. Emphasis is given to those areas which could have a major impact on a risk estimate for TWRS including the source term, BEBA analysis, and consideration of time dependent factors.

4.0 TWRS RISK PROFILE

The TWRS facilities addressed in the safety analysis include underground tanks which store radioactive and chemically hazardous wastes generated during the production of defense-related materials at Hanford through the late 1980’s. There are two primary types of tanks: 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs). The capacity of these tanks range from 2 million L (528,000 gal) to 3.8 million L (1 million gal). There are also 16 small SSTs with a capacity of 208,000 L (55,000 gal). Associated with these storage tanks are facilities for waste transfers between tanks and receipt of waste from rail car or tanker truck. Also included are a number of miscellaneous waste storage and handling facilities, some active and some inactive. The bulk of the waste in TWRS, 228 million L (60 million gal),[11] is stored in the 177 underground storage tanks.

[9] See Table 4.4-2 for the list of BEBA analyses performed.
[10] frequency/dose combinations.
[11] FSAR, page ES-2.

The TWRS operations analyzed include waste storage, waste transfers, waste characterization, and waste concentration. Waste storage includes interim stabilization of SSTs and caustic addition for corrosion control. Transfer operations include internal tank farm waste transfers and transfers from operating (e.g., 242-A Evaporator) or transition facilities (e.g., Plutonium Finishing Plant). Waste characterization includes sampling and monitoring waste and tank conditions. The waste concentration addressed in the TWRS FSAR involves passive evaporation of water due to radioactive decay heat or active ventilation. Waste storage and transfer operations also include monitoring, surveillance, and maintenance activities required to support those operations.

4.1 Constituents of the TWRS Risk Profile

The TWRS risk profile consists of both qualitative and quantitative information. The qualitative information is the result of the hazard analysis activities accomplished to identify the potential hazardous conditions (events) which could result in the uncontrolled release of radioactive and/or hazardous material from TWRS tanks and facilities. Each event identified by the hazard analysis is qualitatively assessed to identify its potential frequency and health and environmental consequences. The identifiers[12] used for the frequency and consequence assessments are shown in Tables 4.1-1 and 4.1-2, respectively. The combination of the event frequency and health consequence assessment defines a risk category for each event. The consequence categories[13] are defined based on the guidance in DOE-STD-3009-94. The more severe consequence categories are defined to include less severe impacts (e.g., S3 consequences always result in S2 and S1 consequences). This method for consequence assessment in hazard analysis has its origins in Department of Defense applications, MIL-STD-882B, *System Safety Program Requirements*.

In Table 4.1-2, the use of the word "significant" requires further explanation. In the case of categories S2 and S3, "significant" means that the risk guidelines in Tables 5.2-1 or 5.2-2 have been exceeded. In the case of category S1, "significant" means the event is life threatening or likely to result in serious injury, and applies only to anticipated events.

Table 4.1-1. Frequency Categories.

Category	Definition
F3 ($>10^{-2}$)	Anticipated events: frequency greater than once in 100 operating years
F2 ($>10^{-4}$ to $\leq 10^{-2}$)	Unlikely: frequency less than or equal to once in 100 years and greater than once in 10,000 operating years
F1 ($>10^{-6}$ to $\leq 10^{-4}$)	Extremely unlikely: frequency less than or equal to once in 10,000 years and greater than once in 1 million years
F0 ($\leq 10^{-6}$)	Beyond extremely unlikely: frequency of less than or equal to once in a million years

Table 4.1-2. Consequence Categories (unmitigated).

Category	Definition
S3	Significant radiological or chemical exposure to the public

[12] FSAR, Section 3.3.1.
[13] DOE-STD-3009-94, Table 3.3.

S2	Significant radiological or chemical exposure to onsite worker
S1	Significant radiological or chemical exposure to facility worker
S0	No significant effect outside facility systems. No consequences to facility workers, onsite workers, or public
E3	Offsite discharge or discharge to groundwater
E2	Significant discharge onsite
E1	Localized discharge of hazardous material
E0	No significant environmental consequence

The purpose of the consequence and frequency categories is to provide an assessment of risk (the combination of consequence and frequency). This assessment supports the selection of accidents for quantitative analysis and the identification of safety controls to provide risk management for TWRS.

An initial set of events, called hazardous conditions, with the potential to result in the uncontrolled release of radioactive and/or hazardous materials, is identified by the hazard analysis. This initial hazard analysis assumes safety controls are not in place. From the set of events with potential offsite (S3) and onsite worker (S2) consequences, accidents are selected for quantitative analysis based on the methodology described in the FSAR, Section 3.3.1.4. This set of accidents is referred to as the "representative accidents". These accidents are selected from the set of events identified by the hazard analysis to bound the potential consequences, cover the range of risks, and address the unique conditions identified in the hazard analysis. Three primary selection requirements are used:

1. Identify bounding consequence case(s).

2. Evaluate the highest risk (consequence and frequency combinations) case(s).

3. Address unique facilities, phenomena, and event initiators for which either the probability of occurrence or the consequences are sufficiently uncertain so as to warrant special treatment.

The representative accidents are used for the initial quantitative assessment of risk and identification of controls. All S2 and S3 hazardous conditions are identified with a representative accident.

The representative accidents for TWRS listed in the Table 4.1-3 are found in the FSAR, Table 3.3.2.3.1-2. Analysis is performed for each accident. This accident analysis to compute the frequency and health consequence results for each representative accident produces the only quantitative risk information in the TWRS risk profile. The risk information for each representative accident includes only the following:

- Frequency: A determination of accident frequency category (Table 4.1-1) which is based on data to the extent possible.

- Consequence: Computation of radiological dose and toxicological consequences (Section 5.2 addresses consequence results).

Table 4.1-3. TWRS Representative Accidents

Nuclear Criticality
In-Tank Fuel Fire/Deflagration
Mixing of Incompatible Material—Tank Pressurization
Flammable Gas Deflagrations—DST
Flammable Gas Deflagrations—SST
HEPA Filter Failure—Exposure to High Temperature or Pressure
Fire in Contaminated Area
Waste Transport Vehicle Accident
Organic Solvent Fire/Organic Salt-Nitrate Reaction
Natural Phenomena—High Wind
Natural Phenomena—Lightning
Tank Failure Due to Excessive Loads
Tank Failure Due to Vacuum or Degradation
Natural Phenomena—Seismic
Spray Leak in Structure or from Overground Waste Transfer Lines
Spray Leak from Underground Waste Transfer Lines
Caustic Spray Leak
Tank Bump
Unfiltered Release
Subsurface Leak Resulting in Pool
Evaporator Dump
Mixing of Incompatible Material—Toxic Vapor Generation
Leak from Railcar/Tank Trailer
Surface Leak Resulting Pool
Unplanned Excavation/Drilling in Crib/Ditch/Pond
Subsurface Leak Remaining Subsurface
Sodium Fire
Aboveground Structure Failure
Steam Intrusion from Interfacing Systems

Only a subset of the representative accidents directly results in a release of material from the large underground waste storage tanks. Table 4.1-4 lists these accidents. While many of the other accidents could release tank waste for associated piping systems, the list of accidents in Table 4.1-4 could result in the release of waste from the tanks themselves. Because of the large inventory of waste in the tanks, these accidents also have the potential for the greatest health consequences. It is important to note that the identified representative accidents (Table 4.1-4) include not only accidents involving the release of tank waste, but also consider the release of only toxicological materials (e.g., caustic spray leaks and sodium fires).

There are TWRS quantitative risk evaluations guidelines for only two populations: (1) the offsite public and (2) the onsite co-located worker (i.e., 100-m receptor). The risk to the facility worker is determined from the consequence assessment derived from hazard analysis results. As described above, if a worker hazard is life threatening or could result in serious injury, and its frequency category is anticipated ($>10^{-2}$ per year), it will be controlled. The risk evaluation guidelines and their use are described in Section 5.2 of this report. Both the hazard and accident analysis results are also used for control selection as described in Section 5.2.

The representative accidents are analyzed both with and without controls to support the selection of controls. The results of the analysis are compared to TWRS' risk evaluation guidelines for the purpose of classifying the controls selected and determining how many levels of controls may be desirable. Consistent with a graded approach to safety, first the accident analysis is performed to determine the consequence and frequency of the representative accidents assuming controls do not exist (‘no controls’ case). The ‘no controls’ case does, however, consider the effects of passive design features (e.g., structures, pipes, barriers) of the systems and/or facilities being analyzed. If the risk is insignificant (i.e., consequences significantly below the risk guidelines presented in Section 5.2 below), then controls are not necessary from a risk management perspective. The purpose of the ‘no controls’ analysis is to:

1. Determine if controls are required to manage the risk of the accident.
2. If controls are required, the safety classification of those controls.

An analysis of the accidents assuming the controls are in place is then performed. The consequences are calculated assuming the controls work as intended with no failures. The purpose of this analysis is to determine how many levels of control(s) may be desirable and to establish an evaluation basis for the accident.

Table 4.1-4. Representative Accidents Directly Associated With Waste Storage Tanks.

Nuclear Criticality
In-Tank Fuel Fire/Deflagration
Mixing of Incompatible Material—Tank Pressurization
Flammable Gas Deflagrations—DST
Flammable Gas Deflagrations—SST
HEPA Filter Failure—Exposure to High Temperature or Pressure
Organic Solvent Fire/Organic Salt-Nitrate Reaction
Natural Phenomena—Lightning
Tank Failure Due to Excessive Loads
Tank Failure Due to Vacuum or Degradation
Natural Phenomena—Seismic
Spray Leak in Structure or from Overground Waste Transfer Lines
Tank Bump
Unfiltered Release
Evaporator Dump
Mixing of Incompatible Material—Toxic Vapor Generation
Subsurface Leak Remaining Subsurface
Steam Intrusion from Interfacing Systems

4.2 Structure of the Safety Analysis

The hazard and accident analysis process is iterative in nature. It is accomplished to identify hazardous conditions, select representative accidents, and identify an adequate set of safety controls. This results in a three-part risk profile:

1. Risk with no controls: The hazard and accident analysis results include frequency and

consequence results assuming no controls are implemented.

2. Risk with selected controls: The accident analysis results include frequency and consequence results assuming the selected controls are implemented (Table 4.2-1 shows accidents with risk results above guidelines with controls).

3. Risk from beyond evaluation basis conditions (Section 4.4 discusses beyond evaluation basis): The hazard and accident analysis results include frequency and consequence results under beyond evaluation basis conditions including assuming failed controls and some selected beyond evaluation basis conditions.

Table 4.2-1. Accidents Above Risk Guidelines (With Controls)[14]

Flammable Gas Deflagrations
Organic Solvent Fire
Organic Salt-Nitrate Reaction
Natural Phenomena (seismic)

There are two principal areas of iteration in the safety analysis process:

1. Between the hazard and accident analysis
2. In the control selection process.

As the safety analysis process proceeds, refinements are made in the risk results. Each set of risk results represents the perceived risk at that stage of the analysis process.

The initial hazard analysis results represent an assessment of the risk prior to the application of controls. From the hazard analysis results, accidents are selected for quantitative analysis (see Section 4.1). If the results of the quantitative accident analysis differ from the qualitative assessment, then the hazard analysis results are refined to reflect the more detailed, quantitative risk results. In this way, the risk results in the hazard and accident analysis are maintained in a consistent manner to support the selection of controls. The control selection process is the other principal iterative activity in the safety analysis. Section 5.2.2 summarizes the iterations in this process.

4.3 Global Analysis Assumptions

Each hazard and accident analysis activity included the identification of assumptions specific to each activity. There are, however, some major assumptions that are used in the both analysis efforts as appropriate. The following lists those assumptions:

- *Graded approach:* The hazard and accident analyses can produce acceptable results using the graded approach. The basis of the graded approach is that the level of sophistication and depth of the analysis is primarily a function of the perceived

[14] These accidents are documented in Section 3.4 of HNF-SD-WM-SAR-067. Each of these accidents are currently the subject of further analysis to refine initial accident analysis results using updated characterization data, more realistic modeling methods, and revised source terms.

magnitude of the risk, but also takes into account the complexity of the systems being analyzed.[15] The level of risk for the TWRS facilities is defined by an iterative process. The hazard analysis first identifies the unmitigated risk and the accident analysis refines that identification through the application of controls. This has resulted in the accident analysis sometimes changing the risk perception identified in the hazard analysis.[16]

- *Representative cases:* Due to the similarity between the large underground storage tanks, it is assumed that representative cases can be analyzed and the results applied to all similar cases. The control decision process developed for the FSAR has a step in it to check this assumption against tank configurations and operations once a control set has been selected based on the representative case. However, this assumption results in only a few cases being analyzed by the hazard and accident analysis and the results applied to all the 177 waste storage tanks.

- *Super tank source term:* Although the contents of tanks may vary, a set of three bounding source terms, sometimes referred to as the "super tank source term," is used to represent the potential releases of tank waste from the storage tanks and related facilities. A source term is used for DST, SST, and Aging Waste Facility (AWF) waste. Section 5.1.1 discusses this source term in more detail.

- *Bounding material transport:* A set of bounding assumptions is used for analyzing the effects of the transport of released material. The two major components of this are (1) the use of 99.5% meteorological dispersion coefficient and (2) ignoring the effects of material re-deposition and lofting effects.

- *Site boundaries:* The site boundary is defined for the public and onsite co-located worker. For the co-located onsite worker, the boundary is 100 m (328 ft) from the point of the release or at the facility boundary in the direction from the point of release at which the maximum dose occurs. For the public, the boundary is located at the distance and in the direction from the point of release at which the maximum dose occurs. This is 8,760m (28,740 ft) to the north or 8,690m (28,510 ft) to the north-northwest, depending on the duration of the release.[17] It is noted that this site boundary for TWRS is different from the site boundary chosen for the RPP-WTP and is slightly less conservative. The distinction will not produce an appreciable difference in the two analyses.

- *Structural integrity:* The hazard and accident analyses assume that the TWRS structures (tanks, buildings, diversion boxes, valve and pump pits, etc.) are sufficient to retain their gross structural integrity under evaluation basis accident conditions (i.e., 1000 year earthquake). This assumption is used to support the position that TWRS structures are features, which can be included in the analysis of release events with no controls.[18] WHC-SD-TWR-RPT-002, *Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste* Tanks, a study of tank structural integrity, supports this assumption for the underground storage tanks.

[15] DOE-STD-3009-94, page 33.
[16] FSAR, Table 3.3.2.3.1-4.
[17] FSAR, page 3.4.1-1.
[18] DOE-STD-3009-94, page 56.

4.4 Analysis of Beyond Evaluation Basis Events

Because TWRS is an existing facility and some of the original design information is not available, the concept of evaluation basis is used in the safety analysis, rather than design basis, to assess the risk of TWRS facilities and operations. The evaluation basis defines a set of conditions for the analysis of accidents in the FSAR. Postulating conditions beyond this basis and re-evaluating the risk from the accidents provides a measure of the level of protection provided by the safety controls identified in the FSAR

Consistent with the DOE order and guidance[19] the assessment of beyond evaluation basis accidents is to provide a perspective of the risk associated with tank farm operations. Beyond evaluation basis accidents are those operational accidents with more severe conditions or failures than are postulated for evaluation basis accidents. DOE-STD-3009-94 also suggests assessments of beyond evaluation basis accidents for natural phenomena accidents but excludes external events.

The evaluation of beyond evaluation basis accidents does not imply that accidents that are considered to be "beyond extremely unlikely" (i.e., $< 1 \times 10^{-6}$ per year) are credible. In fact, the evaluation basis itself does not encompass all events with frequencies $>10^{-6}$. The frequencies of evaluation basis and beyond evaluation basis events are shown in Table 4.4-2. The accident spectrum is reviewed to see if there could be a more severe, but less likely scenario that could contribute significantly to the overall risk posed by the facility. The accident frequencies are reevaluated based on the initiating event and failures that are used to define each beyond evaluation basis accident.

Two types of beyond evaluation basis analyses are addressed in the TWRS FSAR. First, to assess the residual risk from tank farm operations with safety structures, systems, and components (SSCs) and technical safety requirement (TSR) controls in place, analysis is performed postulating failures of SSCs and TSR controls. These assessments are performed for cases where the consequences of accidents without controls are above risk evaluation guidelines.[20] Secondly, to determine if there are residual risks with catastrophic consequences as compared with evaluation basis accidents, potential accident scenarios with phenomena or conditions more severe than evaluation basis accidents are analyzed. Table 4.4-1[21] lists the beyond evaluation basis accidents for TWRS and the conditions analyzed.

In addition to the bounding consequence assessments developed in the evaluation basis, a best estimate of consequences was performed for each beyond evaluation basis accident. The best estimate assessment was performed by examining key assumptions and parameter values in the conservative assessment and comparing them with "nominal" or "typical" values. Commonly, this approach is taken to obtain an assessment (although not a quantification) of the overall risk of the facility. The bounding consequences were divided by the dose reduction factor to approximate a "best estimate" consequence.[22] In some cases, conservatisms were identified but no credit was taken for them in the best estimate analysis because dose reduction values were not readily available or known. Examples of the types of assumptions or parameters evaluated are:

[19] DOE 5480.23 and DOE-STD-3009-94.
[20] Additional analysis for accidents significantly below the risk evaluation guidelines is not performed.
[21] FSAR, Section 3.4.3
[22] See FSAR, Section 3.4.3.1, for the full development of the dose reduction factors for each accident evaluated.

- *Meteorology* - A 50% meteorological dispersion coefficient is used for beyond evaluation basis analyses in contrast with the 99.5% coefficient used in the evaluation basis analysis. Using this assumption reduces consequences by approximately a factor of six.

Table 4.4-1. Beyond Evaluation Basis Analysis

Accident	Condition Analyzed
HEPA Filter Failure—Exposure to High Temperature or Pressure	Failure of Controls
Fire in Contaminated Area	Failure of Controls
Mixing of Incompatible Material-Tank Pressurization	Failure of Controls
Tank Failure Due to Excessive Loads	Failure of Controls
Flammable Gas Deflagrations	Failure of Controls
Organic Solvent Fire	Failure of Controls
In-Tank Fuel Fire/Deflagration	Failure of Controls
Organic Salt-Nitrate Reaction	Failure of Controls
Surface Leak Resulting in Pool	Failure of Controls
Subsurface Leak Resulting in Pool	Failure of Controls
Spray Leak in Structure or from Waste Transfer Lines	Failure of Controls
Tank Bump	Failure of Controls
Natural Phenomena—Seismic	An earthquake with a peak horizontal acceleration of 0.43 *g* and likelihood of 1.3×10^{-4}/yr[23]
Organic Salt-Nitrate Reaction	Burning 200 m^3 (7,063 ft^3) of waste

- *Source Term (or Waste Type)* - Use of a DST solid-liquid combination is used for beyond evaluation basis analyses in contrast to the use of the higher AWF solid-liquid combination in the evaluation basis analysis. Using this assumption reduces consequences by approximately a factor of three.

- *Solids Concentration* - Reducing the percentage of solids in the waste mixture from 33 vol% in the evaluation basis analysis to 5 vol% in the beyond evaluation basis analyses translated into a consequence reduction in the range of 1.3 to 1.8.

The "best estimate" consequences calculated for TWRS are shown in Table 4.4-2. [24]

Another part of the beyond evaluation basis analyses that were performed was to review what impact a failure of the selected controls would have on the evaluation basis accident frequency. The controls, in the aggregate, were considered in the development of each failed controls accident frequency. The results of this evaluation, in comparison with the frequency assessed for the unmitigated evaluation basis accident, are shown in Table 4.4-3. It can be seen from the information in Table 4.4-3 that the frequency of accident, considering the failure of controls, is reduced by at least one frequency category (or bin).

[23] WHC-SD-W236A-TI-002, 1996, *Probabilistic Seismic Hazard Analysis, DOE Hanford Site, Washington*.
[24] Source: FSAR, Section 3.4.3.

Given the extensive disclaimers cited above in Section 3.2, nevertheless, it is possible to calculate a risk-like number from this data. If the individual entries on Table 4.4-2 are combined and multiplied by the logarithmic midpoint of the frequency range for each entry, an estimate of the total risk can be obtained. The result of doing so is 4 mrem/per year exposure to the public and 800 mrem/year to the worker. The worker dose was heavily influenced by seismic for which a frequency of 10^{-4} was selected.

Table 4.4-2. Beyond Evaluation Basis Accidents - Best Estimate Consequence Assessment

Accident description	Accident results with controls		Accident results with failure of controls	
	Frequency category	Consequences (rem)	Frequency category	Best estimate consequence[25] (rem)
HEPA Filter Failure-Exposure To High Temperature Or Pressure	Anticipated	Onsite rad: 6.7E-02	Unlikely	Onsite rad: 9.8 E-02 1.2 E+00[26]
Fire in Contaminated Area	Prevented[27]	Not calculated	Extremely unlikely	Onsite rad: 1.5E+00
Mixing of Incompatible Material-Tank Pressurization	Prevented	Not calculated	Extremely unlikely	Onsite rad: 6.7 E-01
Tank Failure Due To Excessive Loads	Prevented	Not calculated	Extremely unlikely	--
Flammable Gas Deflagrations-Accumulation (SST dome collapse)	Prevented	Not calculated	Extremely unlikely	Onsite rad: 5.0 E-01 Offsite rad: 3.4 E-04
Flammable Gas Deflagrations-Gas release event (SST dome collapse)	Prevented	Not calculated	Unlikely	Onsite rad: 5.0 E-01 Offsite rad: 3.4 E-04
Organic Solvent Fire	Prevented	Not calculated	Unlikely	Onsite rad: 6.1 E-01
In-Tank Fuel Fire/Deflagration	Prevented	Not calculated	Extremely unlikely	--
Organic Salt-Nitrate Reaction	Prevented	Not calculated	Extremely unlikely	Onsite rad: 1.5 E+03 Offsite rad: 1.2 E+00
Surface Leak Resulting in Pool	Anticipated	Onsite rad: 5.1 E-01 Offsite rad: 6.6 E-04	Extremely unlikely	Onsite rad: 3.7 E+00 Offsite rad: 4.0 E-01
Subsurface Leak Resulting in Pool	Anticipated	Onsite rad: 4.2 E-01 Offsite rad: 6.5 E-02	Unlikely	Onsite rad: 1.4 E+01 Offsite rad: 3.2 E-02

[25] Only the consequences that exceed risk guidelines are listed.
[26] Annual unfiltered release.
[27] For accidents in which the controls selected were considered to prevent the scenario, no revised frequency or consequences were calculated.

Table 4.4-2. Beyond Evaluation Basis Accidents - Best Estimate Consequence Assessment

Accident description	Accident results with controls		Accident results with failure of controls	
	Frequency category	Consequences (rem)	Frequency category	Best estimate consequence[25] (rem)
Spray Leak In Structure or from Waste Transfer Lines	Anticipated	Onsite rad: 3.9 E-01 Offsite rad: 1.0 E-04	Unlikely	Onsite rad: 1.4 E+01 Offsite rad: 1.5 E-01
Tank Bump	Prevented	Not calculated	Extremely Unlikely	Onsite rad: 4.2 E+01
Natural Phenomena-Seismic [28]	N/A (see evaluation basis accident outlined above)	N/A (see evaluation basis accident outlined above)	Unlikely	Rad onsite:[29] (1) 3.1 E+01 (2) 5.0 E+03 (3) 1.4 E+02 (4) 5.0 E+03 Rad offsite:[30] (1) 2.7 E-02 (2) 3.4 E+00 (3) 9.3 E-02 (4) 3.5 E+00
Organic Salt-Nitrate Reaction[31]	N/A (see evaluation basis accident outlined above)	N/A (see evaluation basis accident outlined above)	Extremely unlikely	Rad onsite: 1.2 E+04 Rad offsite: 9.8 E+00

[28] This analysis investigates a scenario with phenomena or conditions more severe than the evaluation basis accident; specifically, an earthquake with a peak horizontal acceleration of 0.43 g and likelihood of 1.3 E-04/yr.
[29] Values listed in order of contributions from (1) 4 single-shell tank failures, (2) 1 single-shell tank detonation, (3) 1 double-shell tank detonation, and (4) sum of contributions. For onsite consequences, the sum is considered the highest exposure of any of the accident elements at 100 m (328 ft) because one individual cannot be 100 m (328 ft) from all of the accident elements.
[30] Ibid.
[31] This analysis investigates a scenario with phenomena or conditions more severe than the evaluation basis accident; specifically, burning 200 m^3 (7,063 ft^3 of waste).

Table 4.4-3. Beyond Evaluation Basis Accidents - Accident Frequency Results.

Accident description	Accident with controls	Accident without controls	Accident results with failure of controls
	Frequency category	Frequency category	Frequency category
HEPA Filter Failure-Exposure to High Temperature or Pressure	Anticipated	Anticipated	Unlikely
Fire in Contaminated Area	Anticipated	Prevented[32]	Extremely unlikely
Mixing of Incompatible Material-Tank Pressurization	Anticipated	Prevented	Extremely unlikely
Tank Failure Due to Excessive Loads	Unlikely	Prevented	Extremely unlikely
Flammable Gas Deflagrations-Accumulation (SST dome collapse)	Anticipated	Prevented	Extremely unlikely
Flammable Gas Deflagrations-Gas release event (SST dome collapse)	Anticipated	Prevented	Unlikely
Organic Solvent Fire	Unlikely	Prevented	Unlikely
In-Tank Fuel Fire/Deflagration	Unlikely	Prevented	Extremely unlikely
Organic Salt-Nitrate Reaction	Unlikely	Prevented	Extremely unlikely
Surface Leak Resulting in Pool	Anticipated	Anticipated	Extremely unlikely
Subsurface Leak Resulting in Pool	Anticipated	Anticipated	Unlikely
Spray Leak In Structure or from Waste Transfer Lines	Anticipated	Anticipated	Unlikely
Tank Bump	Unlikely	Prevented	Extremely Unlikely
Natural Phenomena-Seismic	N/A (see evaluation basis accident outlined above)	N/A (see evaluation basis accident outlined above)	Unlikely[33]
Organic Salt-Nitrate Reaction	N/A (see evaluation basis accident outlined above)	N/A (see evaluation basis accident outlined above)	Extremely unlikely

HEPA = high-efficiency particulate air (filter).
rad = radiological consequences.

[32] For accidents in which the controls selected were considered to prevent the scenario, no revised frequency or consequences were calculated.
[33] Frequency of beyond evaluation basis event is 1.3 x 10^{-4}/yr which is lower than the evaluation basis accident frequency of 1.0 x 10^{-3}/yr.

5.0 CURRENT TWRS ANALYSIS BASES

5.1 TWRS Source Term

For TWRS, radiological and toxicological source terms have been developed and approved for use in the accident analysis.

5.1.1 Radiological Source Term

The radiological source term is used to calculate the inhalation (onsite and offsite receptors), ingestion (offsite receptor only), and direct radiation (significant for onsite receptor only) dose components of individual analyzed accidents, as appropriate. The methods used in the development of the radiological source term are documented in WHC-SD-WM-SARR-037, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations*.

Computer modeling was used to identify and estimate the total inventory of radioactive materials contained in fuel from the Hanford Site production reactors. Reduction factors were applied to the total inventory to account for the Plutonium Uranium Extraction Facility. Reduction factors were applied to other isotopes (e.g., cesium and strontium) which also were extracted. Results of the inventory calculations are documented in WHC-SD-WM-RPT-164, *Inventories for Low-Level Waste Tank Waste.*

Computer modeling identified the potential presence of more than 150 radionuclides in the tank waste. The total activity for each radionuclide was multiplied by its inhalation dose conversion factor to determine its relative dose inhalation hazard. Dose conversion factors were taken from EPA-520/1-88-020, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*. The following seven radionuclides were found to contribute approximately 99% of the inhalation dose: ^{90}Sr, ^{90}Y, ^{137}Cs, ^{239}Pu, ^{238}Pu, ^{241}Pu, and ^{241}Am. Two additional radionuclides, ^{237}Np and ^{244}Cm, were added based on process knowledge; and two additional radionuclides, ^{60}Co and ^{154}Eu, were added to account for external exposure considerations.

The in-tank concentrations of the 11 radionuclides are given in Table 5.1.1-1. These concentrations were developed by collecting and evaluating historical sample data and tank content estimates derived from flow sheet-based models and intertank transfer records. Data sources include the following:

- WHC-SD-WM-TI-543, *Radionuclide and Chemical Inventories for the Double-Shell Tanks*

- WHC-SD-WM-TI-565, *Radionuclide and Chemical Inventories for the Single-Shell Tanks*

- WHC-SD-WM-SARR-003, *High-Level Waste Tank Subcriticality Safety Assessment*

- WHC-SD-WM-TI-057, *TRAC: A Preliminary Estimation of the Waste Inventories in Hanford Tanks through 1980*
- WHC-SD-WM-ER-349, *Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Area*
- WHC-SD-WM-ER-350, *Historical Tank Content Estimate for the Southeast Quadrant of the Hanford 200 East Area*
- WHC-SD-WM-ER-351, *Historical Tank Content Estimate for the Northwest Quadrant of the Hanford 200 West Area*
- WHC-SD-WM-ER-352, *Historical Tank Content Estimate for the Southwest Quadrant of the Hanford 200 West Area*.

From the above sources, a database containing more than 11,000 entries was developed. Using this data, scatter plots for each of the 11 radionuclides were generated for both solid and liquid SST, DST, and AWF tank samples. Subject matter experts familiar with the process history of the Hanford Site evaluated the plots and selected the highest value on the plot that (1) was technically possible and (2) did not conflict with known process parameters or contain an obvious error. The result is a composite inventory in which the concentration of each radionuclide is maximized. For example, the composite inventory for DST liquids represents a single tank containing the highest activity concentration for each radionuclide found in the sample data for all DST liquids. The scatter plots and the supporting data, procedures, and assumptions are documented in WHC-SD-WM-ER-400, *Tank Waste Source Term Inventory Validation*. A detailed discussion of the development of the radionuclide inventory is presented in WHC-SD-WM-SARR-037.

The 11 radionuclides that comprise 99+% of the inhalation dose are presented in Table 5.1.1-1. [34] Table 5.1.1-2[35] presents the individual inhalation unit liter doses that have been developed for use in the accident analysis.

Table 5.1.1-1. Derived In-Tank Concentrations of the 11 Radionuclides Chosen for Inclusion in Accident Analysis

Isotope	Concentration (Bq/L)					
	SST liquids	SST solids	DST liquids	DST solids	AWF liquids	AWF solids
^{60}Co	9.53 E+06	4.2 E+08	6.97 E+06	1.5 E+07	7.71 E+05	4.9 E+08
^{90}Sr	1.05 E+10	1.6 E+12	4.59 E+09	5.2 E+10	5.60 E+09	2.9 E+12
^{90}Y	1.05 E+10	1.6 E+12	4.59 E+09	5.2 E+10	5.60 E+09	2.9 E+12
^{137}Cs	2.21 E+10	1.0 E+11	5.86 E+10	5.9 E+10	8.84 E+10	9.8 E+10
^{154}Eu	2.35 E+09	5.8 E+09	4.18 E+07	3.0 E+08	0.00*	1.1 E+10

[34] Source: WHC-SD-WM-SARR-037, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations*.
[35] Ibid. Waste-specific source terms such as double-shell tank liquids and single-shell tank liquids were developed so that accident consequences could be focused on the type of waste that could potentially be released in the accident. This was a logical concept for the safe storage mode of tank farm operations where activities such as interim stabilization were concentrated on moving specific types of wastes (i.e., single-shell liquids and single-shell solids).

Table 5.1.1-1. Derived In-Tank Concentrations of the 11 Radionuclides Chosen for Inclusion in Accident Analysis

Isotope	Concentration (Bq/L)					
	SST liquids	SST solids	DST liquids	DST solids	AWF liquids	AWF solids
^{237}Np	0.00*	3.0 E+07	2.3 E+05	8.1 E+05	9.20 E+04	9.9 E+08
^{238}Pu	9.21 E+04	1.9 E+08	1.78 E+06	7.2 E+07	2.75 E+03	6.7 E+07
^{239}Pu	3.62 E+07	4.4 E+08	7.65 E+06	1.6 E+09	1.20 E+06	4.4 E+08
^{241}Pu	2.57 E+08	3.2 E+09	1.84 E+07	3.8 E+09	3.39 E+05	1.7 E+09
^{241}Am	4.23 E+07	2.3 E+08	3.40 E+07	2.7 E+09	1.10 E+06	1.1 E+10
^{244}Cm	4.23 E+05	2.3 E+06	1.22 E+05	1.6 E+07	1.10 E+04	6.1 E+07

*No valid sample result exists for these isotopes. Analysis indicates these isotopes, in the liquids, are negligible contributors to dose.
AWF = Aging Waste Facility.
DST = double-shell tank.
SST = single-shell tank.

Table 5.1.1-2. Unit Liter Doses for Tank Waste Composites.

Composite	Inhalation ULD (Sv/L)	Ingestion ULD* (Sv-m^3/s-L)
Single-shell tank liquids	1.1 E+04	0.052
Single-shell tank solids	2.2 E+05	4.1
Double-shell tank liquids	6.1 E+03	0.068
Double-shell tank solids	5.3 E+05	0.48
Aging waste facility tank liquids	1.4 E+03	0.092
Aging waste facility tank solids	1.7 E+06	8.1

*Includes 24-h ingestion of fruits and vegetables, ground shine, inadvertent soil ingestion, and inhalation of material resuspended from the ground.
ULD = unit liter dose.

Radiological Source Term Enhancements Currently Underway. A working group from TWRS is currently examining the tank waste sample data that has been compiled by the TWRS Characterization Program for two purposes. The first is to evaluate new radionuclide sample data for the annual update of the radiological source terms used in the FSAR. The second is to determine if the quality and quantity of new sample data, available since the last update of the source term in 1996, would support the development of a new ULD model. The group has preliminarily concluded that the quantity and quality of waste tank sample data now available justifies a change from the super tank source term model to a tank mean based model for developing ULDs for the Tank Farms. The advantage to be gained in adopting the new methodology is that individual, statistically insignificant sample results will not drive the calculation of the ULDs (now shown in Table 5.1.1-2).

Changing from the super tank model, as discussed earlier, to a mean tank model will be a change in the safety approach for TWRS. The intent of the super tank model was to bound the source term component in any possible release scenario. The mean tank model, in contrast, acknowledges that waste with ULDs higher than the ULDs selected for use in the AB

(Table 5.1.1-2) could exist. The statistically based approach allows the customer (i.e., the Office of River Protection) to choose the desired level of conservatism.

The discussion provided above is based on preliminary results provided by the working group.[36]

5.1.2 Toxicological Source Term

The toxicological source term is based on consideration of constituents of liquids and solids in the tank waste and the gases found in the tank vapor space.

Liquids and Solids. The chemical composition of tank wastes has been determined based on an evaluation of currently available data that characterizes the tank waste. Information sources are identical to those listed in Section 5.1.1. The term "analyte" is more appropriate than "chemical" when referring to sample data because laboratory analyses of waste samples are typically designed to detect elements and ions versus full-molecule compounds. Appendix I of HNF-SD-WM-SAR-067 lists analytes and more than 150 associated compounds potentially present in tank waste. The listing is based on an expert review of the data sources. To assess the relative hazard posed by these compounds, a screening process was applied to identify those compounds that (1) can exist in an alkaline environment and (2) pose an acute exposure hazard as a toxic, corrosive, or irritant. Approximately 70 chemical compounds associated with 24 analytes were identified. If a particular analyte occurred in several toxic compounds, limits for the analyte subsequently derived were based on the most restrictive compound. For example, calcium was identified as being present in three compounds: $CaCO_3$, $CaOH\text{-}SiO_2\text{-}H_2O$ gels, and $Ca(OH)_2$. The hydroxide was determined to pose the limiting inhalation hazard because of its corrosiveness. Therefore, all calcium is assumed to be present as $Ca(OH)_2$ even though some would be present as non-corrosive compounds.

Similar to the approach used for radionuclides, scatter plots for each of the 24 analytes were generated for both solid and liquid SST and DST samples, and the concentrations were reviewed by an expert panel to determine the maximum valid concentration. Composites were developed by taking the maximum valid concentration for all the analytes in all the tanks in that composite grouping. For example, the arsenic concentration used for SST liquids is the maximum valid arsenic concentration measured in all SST liquid samples. The composite concentrations for the 24 analytes of concern are presented in Table 5.1.2-1.[37] The scatter plots, along with the supporting data, procedures, and assumptions are documented in WHC-SD-WM-ER-400. A detailed discussion of the development of the chemical inventory is presented in WHC-SD-WM-SARR-011, *Toxic Chemical Considerations for Tank Farm Releases*.

Tank Headspace Gases. Tank headspaces contain gases released from the waste and caused by continuing chemical reactions and vapor pressure changes. Experts conducting gas sampling concluded that Tank 241-C-103 contains the highest concentration of organic gases. Twelve gases are present in Tank 241-C-103 at sufficiently high concentrations to warrant further consideration on the basis of their relative toxicity.
Higher concentrations of ammonia and nitrous oxide have been detected in the headspaces of

[36] Review of draft material and discussion with W. L. Cowley, CH2M Hill Hanford Group, Inc.
[37] Source: WHC-SD-WM-SARR-011, *Toxic Chemical Considerations for Tank Farm Releases*.

tanks other than Tank 241-C-103. Even larger concentrations of these gases exist in tank slurries, and a release to headspace, such as that which occurs during a gas release event (GRE), can result in extremely high concentrations.

Worst-case and maximum steady-state headspace gas composite concentrations are presented in Table 5.1.2-2. The organic concentrations are identical for the two composites and are based on Tank 241-C-103 data. For the worst-case composite, the ammonia and nitrous oxide concentrations are based on Tank 241-SY-101 slurry release data as discussed in WHC-SD-WM-SARR-011. For the maximum steady-state composite, the ammonia and nitrous oxide concentrations were conservatively selected based on headspace sample data that indicates peak steady-state ammonia concentration of 2,000 ppmv and nitrous oxide concentration of 1,400 ppmv.

Toxicological Source Term Enhancements Currently Underway. Similar to the radiological source term enhancements discussed in Section 5.1.1, the toxicological source term is also being re-evaluated. No details on the methods or process that is being used are available at this time.[38]

Table 5.1.2-1. Composite Concentrations for the 24 Analytes at the TWRS Tank Farms

Analyte	Composite concentrations (g/L).			
	SST solids	SST liquids	DST solids	DST liquids
Ammonia (NH_3)	3.3 E-01	5.1 E-01	6.6 E+00	7.1 E+00
Antimony (Sb)	1.5 E+00	3.6 E-03	9.2 E-01	6.4 E-03
Arsenic (As)	1.2 E+00	3.0 E-03	5.7 E+00	1.1 E-02
Barium (Ba)	4.0 E+01	5.3 E-02	5.9 E+00	3.3 E-02
Beryllium (Be)	2.6 E-02	3.0 E-04	2.4 E-01	3.8 E-03
Cadmium (Cd)	1.7 E+00	5.0 E-02	2.6 E+01	7.0 E-02
Calcium (Ca)	5.1 E+01	1.1 E+00	2.6 E+01	1.3 E+00
Cerium (Ce)	9.0 E-01	1.8 E+00	2.6 E+00	5.8 E-02
Chromium (Cr^{+3})	6.9 E+01	a	1.5 E+02	a
Cobalt (Co)	5.4 E-01	1.3 E-03	4.4 E+00	8.8 E-03
Cyanide (CN)	8.2 E+00	5.3 E+00	4.7 E-01	9.1 E-02
Dysprosium (Dy)	a	a	a	a
Lanthanum (La)	5.0 E+01	1.9 E-01	3.0 E+01	1.0 E+00
Mercury (Hg)	5.4 E+01	3.1 E-01	1.2 E-01	2.4 E-04
Neodymium (Nd)	2.4 E-01	1.4 E-01	7.0 E+00	5.6 E-03
Oxalate (C_2O_4)	2.8 E+02	3.7 E+00	2.8 E+02	a
Selenium (Se)	3.5 E+00	8.2 E-02	1.9 E+00	2.8 E-01
Sodium hydroxide (NaOH)	2.1 E+02	2.1 E+02	2.3 E+02	2.1 E+02
Sodium (Na)[b]	4.8 E+02	2.1 E+02	3.5 E+02	2.1 E+02
Tellurium (Te)	2.0 E-01	a	9.3 E-01	2.7 E-03
Thallium (Tl)	1.2 E+00	3.2 E-03	1.5 E+01	3.7 E-02

[38] Ibid.

Table 5.1.2-1. Composite Concentrations for the 24 Analytes at the TWRS Tank Farms

Analyte	Composite concentrations (g/L).			
	SST solids	SST liquids	DST solids	DST liquids
Total organic carbon (TOC)-oxalate[b]	1.0 E+02	4.0 E+01	7.5 E+01	4.0 E+01
Uranium (U)	2.8 E+02	1.8 E+00	4.4 E+01	1.1 E+01
Vanadium (V)	3.3 E-02	4.1 E-03	1.2 E-01	2.1 E-03

Note: The Aging Waste Facility tanks are grouped with the other double-shell tanks for toxicological analysis.

[a] The best available data indicates that there are no significant concentrations of this analyte in this composite.
[b] To avoid counting the same analyte twice, the oxalate concentration was subtracted from the total organic carbon concentration and NaOH was subtracted from the Na concentration.

DST = double-shell tank.
SST = single-shell tank.

Table 5.1.2-2. Worst-Case and Maximum Steady-State Headspace Gas Composite Concentrations.

Gas	Worst-case composite concentration[a]		Maximum steady-state concentration[b]	
	ppmv	mg/m3[c]	ppmv	mg/m3[c]
Acetonitrile	13	21.8	13	21.8
Ammonia	61,300	40,000	2,000	1,300
Benzene	0.4	1.3	0.4	1.3
1,3 Butadiene	0.1	0.19	0.1	0.19
Butanol	58	164	58	164
Dodecane	45	296	45	296
2-Hexanone	0.8	2.7	0.8	2.7
Methylene chloride	2	22	2	22
Nitrous oxide	67,000	110,000	1,400	2,340
Propanenitrile	5	11	5	11
Tributyl phosphate	1	12	1	12
Tridecane	50	390	50	390

[a]Based on worst-case composites including slurry gas released.
[b]Based on worst-case steady-state samples, does not include slurry gas releases.
[c]The conversion from ppmv to mg/m^3 assumes a temperature of 38 C (100 F) and a pressure of 740 torr (0.1 MPa)
.

5.2 Risk Evaluation Guidelines and Control Selection Process

The risk evaluation guidelines that have been established for TWRS are shown in Tables 5.2-1[39] and 5.2-2. [40]

[39] Letter 9651709, from R. F. Bacon, WHC, to J. E. Kinzer, RL, *Tank Waste Remediation System Accident Analysis Risk Evaluation Guidelines*, dated April 22, 1996.
[40] Ibid.

Table 5.2-1. Radiological Risk Guidelines.

Frequency category	Frequency range (yr^{-1})	Effective dose equivalent in rem	
		Onsite	Offsite
Anticipated	$>10^{-2}$ to $\#10^{0}$	5.0 E-01	1.0 E-01
Unlikely	$>10^{-4}$ to $\#10^{-2}$	5.0 E+00	5.0 E-01
Extremely unlikely	$>10^{-6}$ to $\#10^{-4}$	1.0 E+01	4.0 E+00

Table 5.2-2. Toxicological Risk Guidelines.

Frequency category	Frequency range (yr^{-1})	Primary concentration guidelines	
		Onsite	Offsite
Anticipated	$>10^{-2}$ to $\#10^{0}$	#ERPG-1	#PEL-TWA
Unlikely	$>10^{-4}$ to $\#10^{-2}$	#ERPG-2	#ERPG-1
Extremely unlikely	$>10^{-6}$ to $\#10^{-4}$	#ERPG-3	#ERPG-2

ERPG = Emergency Response Planning Guideline.
PEL = permissible exposure limit.
TWA = time-weighted average.

5.2.1 Source and Background of the Risk Evaluation Guidelines

The source of the risk evaluation guidelines is the WHC response letter, dated April 22, 1996, to the DOE-RL direction letter, which established the risk guidelines.

The RL direction letter[41] states that RL was provided specific guidance from DOE Headquarters on the risk evaluation criteria for use in preparing the TWRS FSAR.

> *"For preparation of the Hanford Tank Farms FSAR, WHC will use the risk evaluation guidelines approved for installation of the mixer pump in Tank 241-SY-101, as documented in Revision 0 of WHC-CM-4-46 (Nonreactor Facility Safety Analysis Manual, November 1989). These guidelines include allowable onsite and offsite accident doses as a function of accident probability. They are more conservative than the guidelines contained in the latest revision of the WHC Risk Acceptance Guidelines (WHC-CM-4-46, Revision 4). They provide a reasonable set of interim guidelines for use until the Department's guidelines can be issued."*

The radiological risk guidelines from WHC-CM-4-46, Revision 0, are reproduced in Table 5.2-3.

[41] 96-MSD-069, letter to Dr. A. L. Trego, WHC, from J. E. Kinzer, DOE, *Interim Radiological Dose Acceptance Criteria for the Hanford Tank Farms Safety Analysis*, dated April 8, 1996.

Table 5.2-3. Radiological Risk Guidelines from WHC-CM-4-46, Revision 0.

Probability category	Nominal Range of Annual Probability	Effective dose equivalent in rem	
		Onsite[42]	Offsite[43]
Anticipated	1 to 10^{-2}	$\boxed{0.5}$ - 5	$\boxed{0.1}$ - 0.5
Unlikely	10^{-2} to 10^{-4}	$\boxed{5}$ - 10	$\boxed{0.5}$ - 4
Extremely unlikely	10^{-4} to 10^{-6}	$\boxed{10}$ - 25	$\boxed{4}$ - 25

The specific bases for the numerical radiological guidelines shown in Table 5.2-3 are quoted from WHC-CM-4-46.

> *"The 25 rem ceiling for offsite individuals is well established in the nuclear industry as a siting criterion (DOE Order 6430.1A, LA-10294-MS, and 10 CFR 100) and is also suggested in LA-10294-MS as an offsite risk acceptance criterion for low probability events.*
>
> *Westinghouse Hanford Company has applied the 25 rem as a risk acceptance guideline for both onsite and offsite consequences. It is recognized that consequences of any given accident may be higher onsite than offsite. However, since protective measures will be included in the evaluation of onsite consequences, the guideline of 25 rem is applied as an onsite guideline as well as an offsite guideline for events of low probability. The endpoint for both guidelines is thus established at the point corresponding to an annual probability of 10^{-6} and a dose consequence of 25 rem EDE.*
>
> *Draft DOE Order 5400.XX[44] allows the public to be exposed to 0.5 rem/year EDE as a result of a planned noncontinuous exposure. Since the order states that a continuous exposure is one that is predicted to last longer than 5 years, it can be deduced that a noncontinuous exposure can last up to 5 years. It is therefore conservative to apply this criterion to events with an annual probability of 10^{-2}, which is approximately equivalent to a frequency of one event (exposure) in 100 years. This provides a midpoint for the offsite guideline at an annual probability of 10^{-2} and 0.5 rem EDE or corresponding organ dose equivalents.*
>
> *Draft DOE Order 5400.XX also specifies an annual limit of 0.1 rem EDE for continuous exposure of the public. It is conservative to set this as the limit for events with an annual probability approaching one, which provides an endpoint for the offsite guideline at annual probability of one and 0.1 rem EDE or corresponding organ dose equivalents.*
>
> *The DOE Order 5480.11 specifies an annual limit of 5 rem EDE for occupational exposure. It is therefore conservative to apply this criterion to events with an annual*

[42] "Boxed" values are the lower end of the range specified and are those shown in Table 2.2-1.
[43] Ibid.
[44] It is believed that the draft order cited here was issued as DOE 5400.5, *Radiation Protection of the Public and the Environment,* on February 8, 1990. A review of subsequent revisions of WHC-CM-4-46 did not include a reference to this order.

probability of 10^{-2}. This provides a midpoint for the onsite guideline at an annual probability of 10^{-2} and 5 rem EDE or corresponding organ dose equivalents.

The DOE Order5480.11 specifies a maximum allowable dose of 0.5 rem EDE to the unborn child of a worker. It is conservative to set this as the limit for events with an annual probability of one, which provides an endpoint for the onsite guideline at an annual probability of one and 0.5 rem EDE or corresponding organ dose equivalents."

The April 8, 1996, letter goes on to state:

"It is important to recognize that these guidelines are not evaluation points. They do not provide justification for not examining further risk reduction and not putting into effect additional common sense controls. The assurance of adequate protection for the public, site workers, and the environment requires us to reduce our risks to As Low As Reasonably Achievable (ALARA). This is a direct correlation to the as low as reasonably achievable (ALARA) concept in occupational exposures to radiation."

The concept in the previous passage was referred to in practice as not using the risk evaluation guidelines as a "speed limit". That concept, as it was implemented during the development of the FSAR control suite, is discussed later in Section 5.2.2.

Additionally, the April 8, 1996, letter states that:

"As further guidance, I am directing that unless a single point frequency can be justified, the corresponding consequence limit (in Rem) equal to the lowest Rem limit in a particular frequency range as identified in WHC-CM-4-46, Rev 0 shall be used. Single point frequencies must be justified based on justifiable occurrence frequency data and associated analyses."

The Contractor response, in the letter dated April 22, 1996, to the RL direction letter specifies that the toxicological guidelines that will be used are those established in Revision 4 of WHC-CM-4-46. These are the risk guidelines that are shown in Table 5.2-2.

5.2.2 Control Selection Process

As discussed earlier, the risk evaluation guidelines are used for the purpose of classifying the controls selected and determining how many levels of controls may be desirable. The objective is to identify the necessary and sufficient safety SSCs and TSRs that result in satisfying the risk guidelines and providing Defense-in-Depth. The quantitative radiological risk guidelines for the offsite public and onsite co-located workers are given in Table 5.2-1. The risk evaluation guidelines for TWRS facility workers are not quantitative, but based on preventing events that are life threatening or could result in serious injury and are expected to occur with a frequency $>10^{-2}$ per year. For facility workers, Safety-Significant SSCs and TSRs may be required for hazardous conditions with significant facility worker consequences (S1) and with an uncontrolled frequency of anticipated (F3). Table 5.2-4 is a risk matrix that illustrates the application of the risk evaluation guidelines for all the hazardous conditions. It is based on the guidance in DOE-STD-3009-94.[45] The numerical values for the intersection of the frequency and consequence categories are based on the idea that the risk varies from the most severe in the upper right corner of the matrix to the least in the lower left, and consequences are assigned greater importance than probability. The numerical values are used to sort hazardous conditions by risk to support selection of controls.

The guidelines are used for the cases (hazardous conditions) represented by the representative accidents and to address facility worker risk. The concept is that the higher the risk, the more need for controls. The risk matrix in Table 5.2-4 indicates what type of control decision is made for each hazardous condition based on the assessment of its risk from the hazard analysis.

The relationship between the quantitative risk guidelines and the risk matrix is determined by the frequency/consequence results of the accident analysis. For example, if the most severe consequence result for a hazardous condition (accident) exceeds the dose limit for the onsite worker, drawn from Tables 5.2-1 and 5.2-2, that hazardous condition is considered to have an S2 consequence with the corresponding frequency. This combination of frequency/consequence determines the risk index of a hazardous condition based on Table 5.2-4.[46] If a hazardous condition has a frequency of F2 and a consequence of S2, it has a risk index of 12. For those hazardous conditions not directly analyzed as accidents, the risk index is determined by the frequency and consequence results of the hazard evaluations as refined by the information from the accident analysis.

Table 5.2-4. Risk Matrix

	Safety Consequences			
Likelihood	S0	S1	S2	S3
F3	7	11	14	16
F2	4	8	12	15
F1	2	5	9	13
F0	1	3	6	10

Risk Factor	Considered for Identification of Safety Structures, Systems, and Components and Technical Safety Requirements.	Risk Factor	Requires Identification of Safety Structures, Systems, and Components and Technical Safety Requirements

[45] DOE-STD-3009-94, Figure 3-3.
[46] HNF-SD-WM-TI-764, 1999, *Hazard Analysis Database Report*.

The control selection process is highly iterative, as illustrated by Figure 5.2-1.[47] Controls are selected to address:

- The representative accident analyzed for a specific facility or case
- Other facilities or cases where the accident may potentially occur
- The hazardous conditions represented by the analyzed accident
- Facility worker hazardous conditions that may be related to the representative accident.

As each control case is addressed, the set of controls is subject to modification and/or refinement. These modifications and/or refinements result in reanalysis of accidents and hazardous conditions to determine the impacts on risk of the changes in controls and when an adequate set of controls has been selected. The final set of controls and their risk impacts are identified by the last iteration of the hazard and accident analysis.

5.3 Analysis of TWRS Evaluation Basis Events

The TWRS FSAR defines a set of evaluation bases to support the accident analysis. This set of conditions includes both internal events and natural phenomena. Many of the conditions are accident specific and are identified in the FSAR accident analysis sections.[48] There is also a set of general conditions that are part of the evaluation basis. These are listed in Table 5.3-1.

Table 5.3-1. General Evaluation Basis Conditions for Accident Analysis.

Event Type	Condition
Internal	With controls implemented, no control failure
High Wind (straight)	113km/hr (70 mph) with frequency of $1x10^{-3}$/yr
Lightning	0.06 strikes/yr/km^2 (0.16 strikes/yr/mi^2)
Seismic	0.19 *g* peak horizontal ground acceleration with frequency of $1x10^{-3}$/yr

5.4 Analysis of TWRS External Events

5.4.1 Seismic

In the FSAR, both an evaluation basis and beyond evaluation basis seismic event are evaluated. For TWRS, the evaluation basis seismic accident is defined as an event with a peak horizontal acceleration of 0.19 *g* and a peak vertical acceleration of 0.12 *g*.[49] The expected frequency of such an earthquake is 1 x 10^{-3}/yr. Based on structural analyses of the underground storage tanks (WHC-SD-TWR-RPT-002), tank failures or collapse of other major structures would not be expected from accelerations associated with this evaluation basis earthquake.

Table 5.4.1-1 provides a summary of the seismic accelerations, magnitudes, expected

[47] FSAR, Figure 3.3.1.5-1
[48] FSAR, Sections 3.3.2.4 and 3.4.2.
[49] FSAR, Section 3.3.2.3.1 and WHC-SD-W236A-TI-002.

frequencies, and effects of the seismic events reviewed for TWRS.

As discussed in Section 4.2.1.2 of WHC-SD-TWR-RPT-002, the Tank Farms are classified as Performance Category 3 (PC-3) facilities per DOE 5480.28. The corresponding design basis earthquake for the tank structures located in the 200 Areas of the Hanford Site is 0.26 *g* peak free-field horizontal ground acceleration. However, for existing SSCs that cannot meet this requirement, they may be evaluated for a seismic hazard exceedance probability of twice the recommended value for new SSCs (e.g., a lower peak acceleration) in accordance with DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. For existing SSCs located in the 200 Areas of the Hanford Site this corresponds to a peak horizontal ground acceleration of 0.19 *g* and a peak vertical ground acceleration of 0.12 *g*.

Figure 5.2- 1. Control Identification Process.

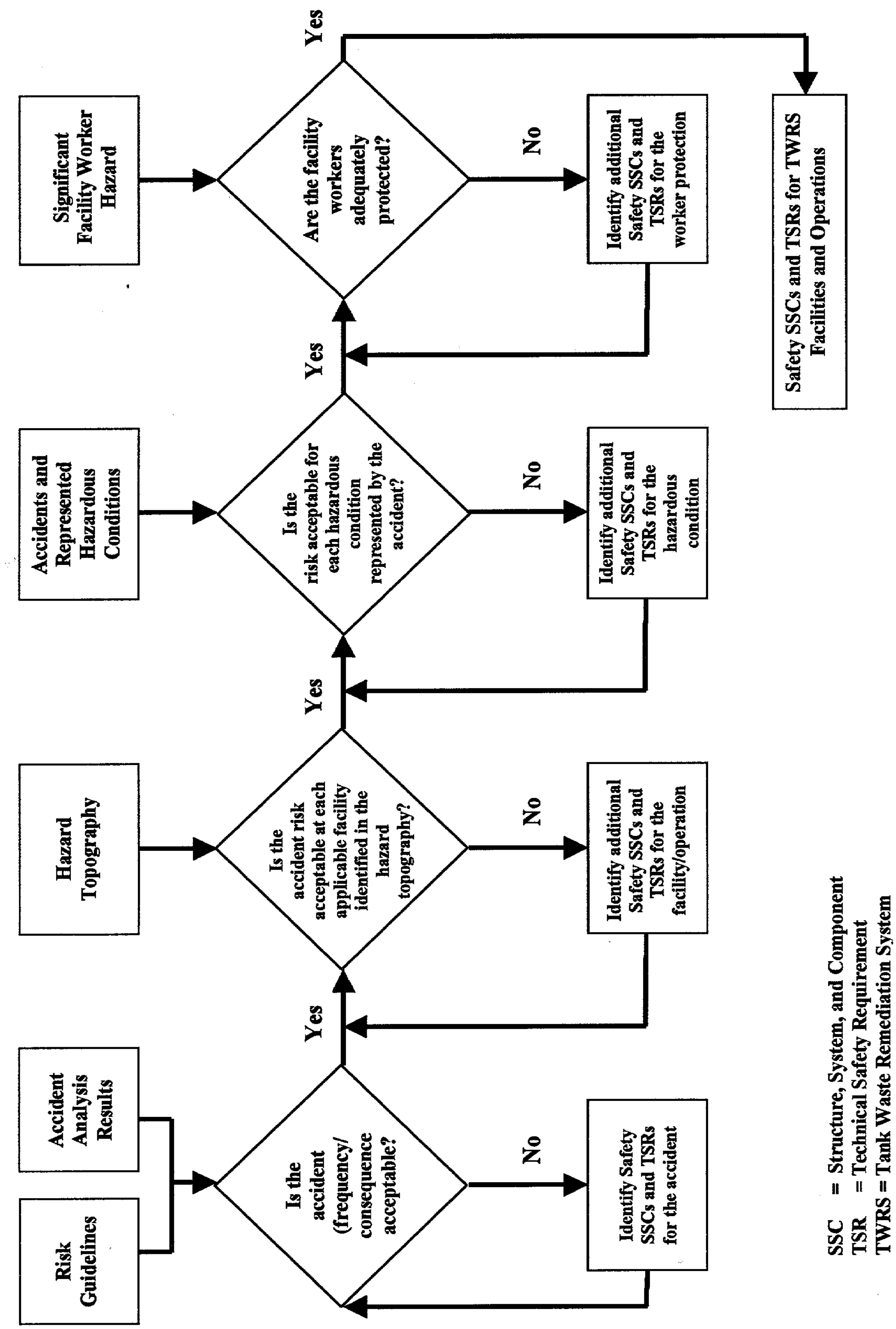

Table 5.4.1-1. Seismic Accelerations, Magnitudes, Expected Frequencies, and Effects.

Peak horizontal ground acceleration	Likelihood of occurrence per year[50]	Description[51]
"Anticipated" Events		
0.05 *g*	> 1.0 E-02	Threshold acceleration above which emergency response actions are implemented. Characteristic of MMI VI. Felt by all. Adobe and weak plaster may crack.
"Unlikely" Events		
0.12 *g*	2.0 E-03	Design criterion for existing Safety-Class 1 facilities per HPS-SDC 4.1. Threshold for evacuation of nonessential personnel. Characteristic of MMI VII. Difficult to stand. Ordinary masonry may crack and weak chimneys may fall.
0.19 *g*	1.0 E-03	Design criterion for existing Performance Category 3 equipment; selected as the FSAR evaluation basis acceleration. Characteristic of MMI VII. Noticed by vehicle drivers. Waves appear on ponds, water turbid with mud.
0.26 *g*	5.0 E-04	Design criterion for new Performance Category 3 equipment for the 200 Area.
0.3 *g*	3.0 E-04	Characteristic of MMI IX. Threshold acceleration for damage to ordinary foundations, potential underground pipe breaks.
0.43 *g*	1.5 E-04	High confidence, low probability of gross leakage of underground storage tank. Characteristic of MMI IX as above.
"Extremely Unlikely" Events		
0.6 *g*	5.0 E-05	Median acceleration for gross leakage of SSTs per WHC-SD-TWR-RPT-002. Characteristic of MMI X. Most ordinary masonry and frame buildings are destroyed.
0.8 *g*	2.0 E-05	Median acceleration for gross leakage of DSTs per WHC-SD-TWR-RPT-002. Characteristic of MMI X. Most ordinary masonry and frame buildings are destroyed.

DST = double-shell tank.
FSAR = Final Safety Analysis Report.
MMI = Modified Mercalli Intensity.
SST = single-shell tank.

Table 5.4.1-2, which has been excerpted from WHC-SD-TWR-RPT-002, compares various correlations for the seismic peak ground acceleration.

[50] Frequency of occurrence based on WHC-SD-W236A-TI-002, 1996, *Probabilistic Seismic Hazard Analysis, DOE Hanford Site, Washington*.
[51] [b]Modified Mercalli Intensity levels and effects based on ORNL-NSIC-28, 1970, *Earthquakes and Nuclear Power Plant Designs*.

Table 5.4.1-2. Seismic Peak Ground Acceleration Correlation.

Current Correlation[52]		Future (DOE Order 5480.28) Correlation[53]	
SC (Reactor)	= 0.25 *g*	PC-4 (Reactor)	= 0.48 *g* (0.37)[54]
SC-1 (High Hazard)	= 0.20 *g*	PC-3 (Safety Class)	= 0.26 *g* (0.19)
SC-2 (Moderate Hazard)	= 0.12 *g*	PC-2 (Safety Significant)	= 0.20 *g* (0.12)
SC-3 (Low Hazard)	= 0.12 *g*	PC-1 (Occupational Safety)	= 0.20 *g* (0.09)
SC-4 (General Use)	= 0.09 *g*	PC-0 (No Safety Significance)	= 0.0 *g*

For purposes of the beyond evaluation basis seismic event, an earthquake with a peak horizontal ground acceleration of 0.43 *g* and likelihood of occurrence of 1.3 x 10^{-4}/yr[55] was selected because it is somewhat beyond the threshold of failure of some underground storage tanks so some tank failures are expected to occur. The likelihood of the overall event assumed for TWRS corresponds to the low frequency end of the "unlikely" frequency category.

For reference, a peak horizontal ground acceleration of 0.43 *g* is larger than the recommended design value for existing PC-4 equipment, which is 0.37 *g* (see Table 5.4.1-1). A 0.43 *g* acceleration is characteristic of Modified Mercalli Intensity IX which typically destroys non-reinforced masonry walls, damages ordinary foundations, and causes underground pipe breaks.[56] The "underground pipe breaks" are actually expected to occur at the termination of underground piping at valve galleries or other locations where the line interfaces with a structure that is responding differently from the surrounding soil.

The median horizontal accelerations for structural failures of SSTs and DSTs are 0.6 *g* and 0.8 g, respectively.[57] However, a 0.43 *g* acceleration corresponds to the high confidence low probability of failure threshold.[58] The FSAR beyond evaluation basis accident assumes that 4 out of 149 SSTs experience structural failures at 0.43 *g*.

The tank structural responses to the above design basis earthquakes vary with the magnitudes of the free-field peak ground accelerations. The failure modes of the tank structure due to seismic excitation could be interpreted in many ways depending on the definition of the failure pattern and potential consequences. In this discussion, the failure mode is defined as that induced from the seismic excitation. Any section of concrete structure experiencing significant cracking to a degree that the concrete section could not resist the applied load and could not function as a continuous integral part of the concrete structure is considered to have failed. The on-set ground acceleration for this failure mode is assumed as the limiting earthquake load.

[52] "Current Correlation" refers to the standards and requirements upon which seismic design criteria were based prior to the implementation of DOE 5480.28. These standards and requirements included SDC 4.1, *Standard Arch-Civil Criteria-Design Loads for Facilities*, and DOE 6430.1A, *General Design Criteria for U.S. Department of Energy.*
[53] Tentative values for 200 West Area, based on new seismic hazard studies.
[54] Values shown in parentheses ( ) are site-specific values for existing structures with seismic hazard exceedance probability of twice the recommended value for new structures.
[55] WHC-SD-W236A-TI-002.
[56] ORNL-NSIC-28.
[57] WHC-SD-TWR-RPT-002.
[58] LA-UR-96-1900, *Probabilistic Safety Assessment for Hanford High-Level Waste Tanks*.

An independent DELPHI expert panel evaluated the tank structure of SSTs and DSTs for seismic loads. Their findings are documented in WHC-SD-TWR-RPT-003[59] and are similar to the assessments described in WHC-SD-TWR-RPT-002. The DELPHI panel's conclusions related to seismic failures are summarized here.

The SSTs begin to fail at an acceleration of about 0.6 *g*. This failure mode is defined as follows:

- Localized shear failure of the wall near the footing.
- Failure of the liner at some locations due to wall failure near footing.
- Dome cracking on both the inner and outer face.
- No continuous large through-the-thickness cracking of dome.
- Some spalling on inner wall of dome due to high dynamic compressive stress.

The DSTs begin to fail at an acceleration level of about 0.8 *g*. This failure mode is defined as follows:

- Base of wall shear damage; wall may "walk".
- Dome cracking.
- Primary liner holds; no release from the dome.
- Possible leakage may occur, and welds may crack.
- Secondary liner at the wall base would be damaged.

A probability safety assessment report[60] presented the results of a risk evaluation of all 177 waste storage tanks. The basis used to determine the failure mode and the corresponding ground acceleration in that report was obtained from the assessment of the 241-AX probabilistic capacity,[61] which defined the failure mode as the circumferential tensile failure of the tank dome near the haunch. It further stated that this failure mode is controlled largely by the horizontal seismic input. Loads from vertical seismic input and hydrodynamic response of the tank contents were found to have no impact on the failure mode and only a small impact on the estimate of the factor of safety. This definition of failure mode is assuming that the circumferential tensile stress, which causes dome failure near the haunch, is continuous along the dome circumference. Since seismic loads are non-axisymmetrical, any structure subject to the seismic excitation during an earthquake event would have compression on one side and tension on the opposite side. It is not likely to have either tensile or compressive stress all around in the structure at the same time. The risk evaluation assumed that the SST dome collapse was due to circumferential tensile failure caused by a horizontal ground acceleration of 0.43 *g*. The dome collapse here is defined as the entire dome shearing off and falling straight down into the tank as a complete section. This assumption is very conservative. In Section 5.6.4 of WHC-SD-TWR-RPT-002, the on-set ground acceleration for tank failure (shear cracks at lower wall near the base mat) is 0.6 *g*. The difference in g-levels (0.43 *g* versus 0.6 *g*) that cause the tank failure is solely dependent upon the conservatism considered in the assumptions. A more conservative approach would result in lower g-level and vice versa. The 0.6 *g* ground acceleration is based on the evaluation of the existing analytical data and typical structural

[59] WHC-SD-TWR-RPT-003, *DELPHI Expert Panel Evaluation of Hanford High Level Waste Tank Failure Modes and Release Quantities*.
[60] LA-UR-96-1900.
[61] EQE, 1993, *Probabilistic Capacity of the 241-AX Underground Waste Storage Tanks to Withstand Seismic Excitation*, EQE Engineering Consultants.

behavior of the tanks during a seismic excitation and is considered an adequate load for the SST failure mode.

Similarly, the 0.8 *g* ground acceleration for the onset of failure of the DSTs, as discussed in Section 5.6.5 of WHC-SD-TWR-RPT-002 is an appropriate and justifiable seismic load. Consequences of a catastrophic tank failure have not been calculated.

5.4.2 High Winds

High winds at TWRS facilities pose a natural phenomenon hazard because winds could initiate single or multiple accidents from a common cause. Both straight winds and tornadoes at TWRS facilities have been characterized.[62]

DOE-STD-1020-94 was used as guidance in the development of the TWRS FSAR to determine the facility-appropriate design wind speeds, depending on the facility hazard category and Performance Category of equipment. For existing TWRS Hazard Category 2 facilities with Performance Category 3 equipment such as underground storage tanks, a straight "fastest mile" wind speed of 113 km/h (70 mph) and a return frequency of 1 x 10^{-3}/yr is used for the evaluation basis.[63] Analysis of wind-blown missiles is not required per DOE-STD-1020-94, for existing Hazard Category 2 facilities with Performance Category 3 equipment. More severe wind speeds are considered only in beyond evaluation basis accident assessments.

For TWRS, four accident scenarios that include wind as a accident initiator are evaluated. These include (1) the transport of waste samples, (2) the collapse of a crane boom, (3) a tear or puncture of a flexible receiver bag, and (4) the failure of a building that is used to store slightly radioactive solidified sodium. Each of these accidents result in calculated consequences that do not challenge either the onsite or offsite risk evaluation guidelines and are detailed in the FSAR.[64]

5.4.3 Flooding

Natural (due to rainfall or dam failure) and man-made (service water line breaks) flooding events have been evaluated for TWRS facilities.

Natural flooding was considered during the hazard assessment but eliminated from the hazard analysis because the tank farm elevations are above the maximum postulated flood level. HNF-SD-WM-SAR-067[65] identifies the natural flood with the potential to impact tank farms. This flood of Cold Creek is a postulated maximum flood caused by precipitation which reaches an elevation of about 195 m (640 ft) above mean sea level on the southwestern portion of the 200 West Area. Because the surface elevation of the lowest elevation tank farms (i.e., 241-S, 241-SY, 241-SX, and 241-U) is 201 to 204 m (660 to 670 ft) above mean sea level, surface

[62] FSAR, Section 1.1.
[63] FSAR, Table 1-33.
[64] In order of text presentation, the listed events can be found in FSAR: (1) Section 3.4.2.12.1, Part A; (2) Section 3.4.2.12.1, Part B; (3) Section 3.4.2.12.1, Part C; and (4) Section 3.3.2.4.10.
[65] FSAR, Section 1.4.2.1.3.

flooding is not anticipated; however, the bottoms of the tanks are below the flood level. Because of the expected short duration of precipitation-caused floods, a significant rise in the water table in these areas is not anticipated, therefore, the tanks would not be impacted.
Flood scenarios with potential for longer residence time were evaluated by the U.S. Army Corps of Engineers.[66] The bounding scenario as described in HNF-SD-WM-SAR-067,[67] resulting in the largest realistically conceivable flow on the Columbia River from either a natural or human caused dam failure, was postulated to be a 50% breach of Grand Coulee Dam. This breach was determined to result in a flood level of about 143 m (470 ft) above mean sea level at river mile 365, which is well below the bottom of the lowest elevation tank. UCRL-21069 provides detailed hazard assessment of other flood scenarios.[68]

The design of TWRS tank farms and the average annual rainfall at the Hanford Site of 168 (6.6 in.)[69] precludes the possibility that enough storm water will accumulate on top of the tanks to cause a release of radioactive or hazardous materials in the tanks.

Flooding in the tank farms caused by system failures was included in the hazard analysis.[70] In the specific evaluation performed, it is postulated that a 0.36 m (14 in.) raw water main breaks. The water released from this break flows into the 241-AW tank farm. By calculating the maximum water flow from the broken raw water line and the drainage rate out of the 241-AW tank farm, it is discovered that water can drain out of the 241-AW tank farm at more than twice the 200 East water system pump capacity before intrusion into the tank could occur. Therefore, water intrusion into the tank farms tanks is not expected as a result of a catastrophic raw water main failure despite the development of a pool that could be as much as 0.06 m (~2 in.) deep.[71]

5.4.4 Aircraft Crashes

The volume of air traffic and the proximity of the airports nearest to the Hanford Site are discussed in FSAR, Section 1.6. Considering this information, the hazard evaluations performed for TWRS identified aircraft crashes (both fixed wing and rotary wing) as a potential cause of some hazardous conditions (e.g., uncontrolled release of radioactive and/or hazardous material). However, these events were not carried forth for accident selection and control decisions. This was because the likelihood of aircraft crashes is considered to be "beyond extremely unlikely." An assessment of the likelihood of aircraft crashes for a proposed Multi-Function Waste Tank Facility confirms this estimate.[72]

5.4.5 Range Fires

Range fires were considered during the development of the hazard analysis information for TWRS. These type of events were specifically included in the assessment of accident frequency for scenarios which included in-tank fuel fires, fires in contaminated areas, and ventilation

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[66] *Artificial Flood Possibilities on the Columbia River*, 1951, U.S. Army Corps of Engineers.
[67] FSAR, Section 1.4.2.1.1.
[68] UCRL-21069, 1988, *Probabilistic Flood Hazard Assessment for the N Reactor, Hanford, Washington*.
[69] FSAR, Section 1.4.1.1.2.
[70] HNF-SD-WM-CN-094, 1997, *Waste Tank Intrusion Due to Raw Water Pipe Failure*.
[71] HNF-SD-WM-CN-094, page 10.
[72] WHC-SD-W236A-ANAL-002, 1994, *Additional Analysis Related to the Multi-Function Waste Tank Facility*.

system releases. Controls specifically to prevent range fires within the tank farm boundaries were not selected based on the severity of other types of fire events that could be potentially created independent of a range fire. Such scenarios included flammable gas deflagrations, organic solvent fires, and organic salt-nitrate reactions.

5.4.6 Impacts from Other Hanford Site or Nearby Facilities

Potential hazards to TWRS facilities from onsite or offsite hazardous operations or facilities were examined under three general classifications:

1. Nonreactor nuclear and non-nuclear industrial facilities within 8 km (5 mi) of the TWRS facility sites, including all activities conducted in and near the 200 East and West Areas. Those facilities evaluated were:

   - Burial grounds (200 Areas)
   - Inactive cribs, ditches, and ponds (200 Areas)
   - Liquid Effluent Retention Facility
   - Effluent Treatment Facility
   - T Plant
   - U Plant
   - Reduction-Oxidation Facility
   - 222-S Laboratory
   - Critical Mass Laboratory (200 East Area)
   - PUREX
   - Grout Treatment Facility
   - B Plant
   - Waste Encapsulation and Storage Facility
   - 242-A Evaporator
   - Plutonium Finishing Plant
   - Low-Level Waste Disposal Site
   - K Basins (100 Areas)
   - Warehouses, fabrication shops, and supply storage areas in the 200 Areas
   - 242-A Evaporator Package Boiler System (local steam generation facility)
   - Raw water treatment facilities (200 Areas)
   - Electrical power generating stations (200 Areas)

   Each of the postulated facility accidents investigated has the potential to impact TWRS operations; however, if a release occurs, the impacts and response actions (facility or Hanford Site) are identified in the facility (where the release originated), TWRS, and Hanford Site emergency response plans in DOE/RL-93-75, *Hanford Facility Contingency Plan*. As appropriate, impacts associated with interfacing facilities (i.e., facilities interfacing with TWRS that have the potential to initiate an accident at a TWRS facility) were addressed in the FSAR, Chapter 3.0.

2. Nuclear reactors within an 8-km (5-mi) radius of the tank farms. The specific facilities considered for their hazard potential to TWRS were:

    - N Reactor
    - Fast Flux Test Facility
    - WNP-2 (Energy Northwest Nuclear Power Plant).

    Worst-case events that have been postulated for each of these facilities do not carry any potential for adversely impacting TWRS operations or personnel.

3. Military activities. The specific facilities considered for their hazard potential to TWRS were:

    - Umatilla Army Depot
    - Yakima Firing Center.

    The most probable hazard to Hanford Site facilities from these facilities is a scenario in which a fire starts within the boundaries of the Yakima Firing Center and spreads to the Hanford Site. It is postulated that exploding artillery shells and sparks from tracked vehicles or other machines may start brush fires that, under adverse meteorological conditions, could rapidly spread beyond the firing center boundaries. The hazards associated with range fires are discussed in Section 5.4.5 above.

5.5 Common Cause Failures

5.5.1 Loss of AC Power

Loss of electrical power was considered in the common cause failures analysis that was performed for TWRS. The consequences of a loss of electrical power at TWRS would include a failure of automatic monitoring, loss of active ventilation flow, and the loss of pumping capabilities. The most serious of these failures would be the loss of active ventilation that could lead to a build-up of flammable gas in the waste storage tanks. However, analysis shows that for even the worst-case DST it would take approximately 32 days after the ventilation system failure to reach the lower flammability limit.[73]

Additionally, the safety analysis for TWRS has not identified any accidents that could be immediately caused by the loss of electrical power to electrically powered safety SSCs. None of the safety SSCs selected for TWRS requires continuous electrical power to adequately perform their safety functions. Backup generators are installed in some areas of TWRS, but are not required to start up immediately upon loss of Site power to protect the safety functions of the safety SSCs. The accident analyses show, instead, that electrical power to electrically powered safety SSCs can be interrupted temporarily without significant compromising facility safety.

[73] FSAR, Section 3.4.2.2.5.

5.5.2 Other Common Cause Failures

The other types of common cause failures that are considered in the hazard analysis for TWRS are shown in Table 5.5-1. [74]

Table 5.5-1. Other Common Cause Failures.

Loss of water supply
Loss of steam supply
Loss of fuel supply
Loss of air supply
Disabled or unavailable staff
Poor quality materials
Aging effects
Chemical phenomena

None of these are considered to pose a risk significant enough to warrant additional analysis.

6.0 TREATMENT OF TIME-DEPENDENT FACTORS

6.1 Tank Structural Integrity

In the TWRS FSAR, tank structural failures that only result in leaks to the soil are not treated as accidents, but only considered for their potential TWRS worker and environmental impact. This is because leaks to the ground do not immediately result in adverse health effects to the public or onsite workers. Only those failure events that have the potential to immediately expose the public or onsite workers are represented by the accidents analyzed under the title "Tank Failure Due to Excessive Loads" (includes tank failure due to vacuum and degradation). Therefore, the FSAR only addressed the issue of tank structural integrity in the context of how it impacts potential accidents. The following accident scenarios are identified as those that could lead to tank structural failure due to vacuum or degradation. [75]

- Aging of the tank structure as the result of thermal cycling, corrosion, and level cycling.
- Excessive vacuum caused by (1) failures in the ventilation system with continued exhaust operation, (2) cool down after certain accidents (e.g., fire), or (3) cooling of the atmosphere or waste as the result of the addition of water.
- High concrete temperatures as a result of ventilation failure, heat load in excess of design conditions, or thermal characteristics that result in "hot spots."
- Accelerated wall or rebar corrosion or degradation as the result of corrosive chemicals added to the tank.

[74] FSAR, Table 3.3.2.1.3-1.
[75] FSAR, Section 3.4.2.1

All these potential tank failures relate to the issue of how tank structural integrity reacts over time. Two reports[76] contain details of the structural analyses performed to determine the severity of these tank failure hazards. The following summarizes those results:

Tank Structural Aging—The effects of structural aging on the failure rates of TWRS tanks (DSTs, SSTs, double-contained receiver tanks [DCRTs], catch tanks, and 20-ft-dia SSTs) were evaluated. Aging of the tank structure is a slow process of degradation that includes corrosion, thermal cycling, and stress-cycling caused by waste level changes. Tank failures that are the result of structural aging do not result in releases from the tank domes because the aging processes have a much more pronounced effect on the walls of a tank than on the dome. In the worst-case DST or SST accident for this scenario, a tank could experience wall failure and subsequent dome movement, but the dome would remain intact.[77]

Excessive Vacuum—The failure rates of TWRS tanks (DSTs, SSTs, DCRTs, catch tanks, and 20-ft-dia SSTs) were evaluated assuming a vacuum loading of up to -55 kPa (-8 lb/in.^{2} gauge). Excessive vacuum does not result in releases from the domes of DSTs or SSTs because the concrete tank walls and domes can withstand relative vacuums of up to -55 kPa (-8 lb/in.^{2} gauge). This threshold bounds a vacuum from fire, ventilation system failure (i.e., exhaust fan with all flow paths blocked), and cooling of the dome space from water spray.

High Concrete Temperatures—Postulated failures of the TWRS tanks (DSTs, SSTs, DCRTs, catch tanks, and 20-ft-dia SSTs) were evaluated based on studies of Hanford Site high tank temperatures. Heat transfer studies of the effects of loss of cooling show that wall temperatures next to waste with the greatest heat loads (e.g., Tank 241-A-106 in 1963) may have reached 243 °C to 284 °C (471 °F to 544 °F), but tank dome temperatures did not exceed 121 °C (250 °F).[78] Under such temperature conditions DST and SST walls may lose strength, but the structural properties of the dome are unchanged.[79] Ventilation outages of at least three years in duration are required before tank walls lose strength.[80]

Accelerated Wall Corrosion and Degradation—The presence of improper chemicals in tank waste could result in accelerated tank corrosion or degradation. Effects of the presence of such chemicals are addressed in the evaluation of tank structural integrity documented in WHC-SD-TWR-RPT-002. This report assesses the impact of corrosion on the tank structural concrete, concrete reinforcing steel (rebar), and the tank liners. For both the tank structural concrete and rebar, the evaluation concludes that neither structural component of the tanks has likely experienced significant strength degradation as a result of corrosion. The evaluation of the tank liner showed significantly different results, however. Given that the waste solution was directly in contact with the steel liner, this portion of the tank experienced the most direct corrosion. For many SSTs, the steel liners have failed and leaked waste to the soil. The report assesses that the DSTs may have also suffered localized corrosion attack and possibly uniform corrosion in the vapor phase regions, although none have leaked. The DSTs have not leaked most likely because of their improved design (over the SSTs), required post-weld thermal stress

[76] WHC-SD-TWR-RPT-002, and WHC-SD-WM-TI-775, 1996, *Structural Assessment of Accident Loads*.
[77] WHC-SD-WM-ER-414, 1995, *Hanford Waste Tank System Degradation Mechanisms Report*.
[78] RHO-SD-RE-TI-037, 1982, *Tank 241-A-106 Steady State Heat Transfer Analysis*, and RHO-LD-171, 1981, *Heat Transfer Analysis for In-Situ Disposal of Nuclear Wastes in Single- and Double-Shell Underground Storage Tanks*.
[79] BNL-52384, 1993, *Thermal Degradation of Concrete in the Temperature Range from Ambient to 315 C (600 F)*
[80] WHC-SD-WM-SARR-010, 1995, *Heat Removal Characteristics of Waste Storage Tanks*.

relief, better control of waste chemistry, and exposure to less severe thermal conditions.[81]

Seismic events can also challenge the structural integrity of the TWRS tanks. For existing Hazard Category 2 facilities with Performance Category 3 equipment, such as TWRS, a peak horizontal ground acceleration of 0.19*g* and a return frequency of 10^{-3}/yr is used as the evaluation basis seismic event.[82] Based on structural analyses of the underground storage tanks,[83] tank failures or collapse of major structures would not be expected from accelerations associated with an evaluation basis earthquake. An independent seismic assessment performed for the U.S. Department of Energy-Richland Operations Office reached the same conclusion.[84]

The conclusion of the FSAR analysis is that tank structural integrity is sufficient to support the level of safety identified in the FSAR. Not withstanding this conclusion, the FSAR Safety Evaluation Report directs the contractor to "outline an in-service inspection program to assess and maintain the integrity of TWRS facilities."[85] Consequences of a catastrophic tank failure have not been calculated.

6.2 Equipment Aging and Reliability

The equipment identified in the TWRS Authorization Basis (AB) as safety controls primarily consists of existing TWRS SSCs. Some of these structures and equipment are more than 50 years old with the first SSTs being constructed in 1943.[86] There are concerns that the age and condition of the existing TWRS equipment may mean upgrades are required to achieve the equipment reliability identified in the FSAR.[87] However, the FSAR concludes that "The TWRS safety SSCs identified in the FSAR do not require "retrofit" or "rework" to any upgrading criteria."[88] Recent experiential data combined with reliability analysis demonstrates that some equipment is providing the availability assumed in the control selection process.[89]

The FSAR states that "To achieve and sustain safe operations, a comprehensive program of management oversight and assessment covering operations, surveillance and maintenance practices, feedback of operational experience, and overall effectiveness of management controls … shall be maintained."[90] This conclusion is based on three factors:

1. Over the years, some safety related systems and equipment have been upgraded with the last DSTs being built in 1986 and subsequent system upgrades and new projects continuing to the present (1999).

2. The safety functions identified for the SSCs can be effectively performed by commercial grade equipment or require only "gross structural integrity" be maintained.[91]

[81] WHC-SD-TWR-RPT-002, page 3-9.
[82] WHC-SD-W236A-TI-002, Chapter 1.0, Table 1-32.
[83] WHC-SD-TWR-RPT-002.
[84] RLCA/P286-02-01-96/001, 1996, *Evaluation of Hanford High Level Waste Tank Failure Modes for Seismic Loading*.
[85] TWRS-RT-SER-003, 1999, *Safety Evaluation Report for the Tank Waste Remediation System (TWRS) Final Safety Analysis Report (FSAR) and Technical Safety Requirements*.
[86] FSAR, page 2-8.
[87] TWRS-RT-SER-003, Attachment 3.
[88] FSAR, page 4-2.
[89] RPP-5453, 2000, *Availability Analysis of the Ventilation Stack CAM Interlock System*.
[90] FSAR, page 4-5.
[91] FSAR, Chapter 4.0.

3. DOE made clear its intent to develop safety analyses that established and evaluated the adequacy of the safety bases for operation of their nonreactor nuclear facilities. These analyses were not to upgrade the newly identified safety SSCs in existing systems.

The FSAR states that although some experience with equipment reliability has been less than satisfactory, modifications that will enhance the reliability and performance of the TWRS safety SSCs, will ultimately decrease the residual risk of TWRS operations. Each safety related SSC identified in the AB has the reliability performance assumed in the hazard and accident analyses.[92]

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[92] FSAR, pages 4-3 and 4-4.
[93] It is believed that the draft order cited here was issued as DOE 5400.5, *Radiation Protection of the Public and the Environment,* on February 8, 1990. A review of subsequent revisions of WHC-CM-4-46 did not include a reference to this order.

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8.0 LIST OF TERMS

AB	authorization basis
ALARA	as low as reasonably achievable
AWF	Aging Waste Facility
BEBA	beyond evaluation basis accident
DCRT	double-contained receiver tank
DOE	U.S. Department of Energy
DST	double-shell tank
EDE	effective dose equivalent
ERPG	Emergency Response Planning Guideline
FSAR	Final Safety Analysis Report
GRE	gas release event
HEPA	high-efficiency particulate air (filter)

MMI	Modified Mercalli Intensity
NRC	U.S. Nuclear Regulatory Commission
PC	Performance Category
PEL	permissible exposure limit
PRA	probabilistic risk assessment
PUREX	Plutonium Uranium Extraction (Facility)
REG	risk evaluation guideline
RL	Richland Operations Office
RPP-WTP	River Protection Project Waste Treatment Plant
SSC	structure, system, and component
SST	single-shell tank
TSR	technical safety requirement
TWA	time-weighted average
TWRS	Tank Waste Remediation System
ULD	unit liter dose
WHC	Westinghouse Hanford Company